Chapter III - GEOTECHNICAL ENGINEERING

SECTION 301 GENERAL

Geotechnics is defined as "the application of scientific methods and engineering principles to the acquisition, interpretation and use of knowledge of materials of the earth's crust to the solution of civil engineering problems. It embraces the fields of soil mechanics and rock mechanics and many of the engineering aspects of geology, geophysics, hydrology and related sciences." (Glossary of Geology, American Geological Institute, Washington, DC 1972.)

Within the Materials Division, the field of Geotechnical engineering for highway design, construction, and maintenance, therefore, includes the activities of the Geology, the Soils, and the Foundations Engineering Sections.

The main objective of the geotechnical investigations is to acquire data needed for the design of roadway foundations, cut and fill slopes, soil stabilization and retaining systems, and structure foundations.

Typically, the geotechnical investigation should accomplish the following:

(1) Locate and identify the various soil and/or rock types within the limits of the project.

(2) Measure the capacity for the material to support loads (bearing capacity) at various depths beneath sites where structure footings will be located.

(3) Provide representative samples of each soil type or stratum for testing in the Soils Laboratory.

   (a) Obtain disturbed samples for routine testing to determine the soil's particle size distribution, moisture content, liquid and plastic limits, etc.

   (b) Obtain undisturbed (Shelby tube) samples for testing to determine the rate of soil consolidation when loading is applied, and to determine the shear (failure) strength of the soil under various loading conditions.

(4) Measure ground water levels and determine the potential for corrosion (pH).

(5) Identify any geological constraints or conditions that may have an adverse effect on the project.

(6) Provide information for scour analysis when the proposed construction will bridge streams as part of the foundation evaluation

Prior to beginning drilling, the crew chief should inspect the drill site to identify any signs that might indicate the presence of buried hazardous waste. Liquid seepage, soil discoloration, odors, abnormalities in vegetation, and extensive filling and regrading of the land in remote areas are some characteristics that may indicate the presence of buried waste. These conditions should be reported to the District Materials Engineer for further checking and clearance. Evidence of environmentally hazardous materials and/or contamination should be reported to the District Environmental Engineer.

If, during the progress of the boring, the drill should puncture buried pipes, drums, tanks, or sever wires or cables, drilling should be suspended immediately, the drilling tools left in the ground, and the area around the drill cleared. The District Materials Engineer and appropriate utilities, Department of Environmental Quality, or Hazardous Response Team should immediately be notified and given all the details relating to the incident.

SECTION 302 TYPES OF INVESTIGATIONS

Primarily, geotechnical investigations are the routine soil surveys and structure foundation investigations carried out during the preliminary engineering phase of a project. Occasionally, however, special geotechnical investigations are required to provide data for the solution of stability problems-landslides, fill failures, sink holes and embankment settlement-that may occur from time to time; or to investigate claims alleging damage to private property by transportation construction activities. Vibration (seismic) investigations, ground water pollution studies, and water well damage investigations are examples of claim investigations.

This Manual, however, will cover in detail only routine geotechnical investigations (the soil surveys and the structure foundation investigations) that are ongoing functions of the Preliminary Engineering Sections. Special investigations carried out during the construction phase of a project or for maintenance purposes will not be covered.

SECTION 303 INVESTIGATION PROCEDURES

Sec. 303.01 General

The District Administrator, District Engineer for Construction and the District Materials Engineer shall be responsible for conducting a preliminary engineering investigation in the field, and literature reviews of existing county mapping of potential problem soils.. Drill crews assigned to the District Materials Section will be responsible for sampling and in-situ testing of materials in their natural state. The District Geologist and/or Materials Technician Supervisor for preliminary engineering work will be responsible for supervising and coordinating the work of the drill crews.

In situations that require the use of outside assistance or the assistance of the staff at the Central Materials Laboratory at Elko, the District Materials Engineer will request such assistance through the Assistant State Materials Engineer responsible for Preliminary Engineering. Requests for special investigations which originate outside the Materials Division shall be routed in a similar manner.

Seventy-two hours prior to beginning any drilling the crew chief shall contact Miss Utility. If at all possible the job should be staked prior to the call so that the utility locator will have specific locations to check. Miss Utility should be instructed to call back with an “all clear” or have each utility locator call back with specific information as to the location of each utility and his marking system.

Sec. 303.02 Permission to Enter Property

No investigation is to be undertaken on any property which is not within highway right-of-way without first obtaining permission from the property owner or from the person having authority to grant such permission. This restriction includes the crossing of property by personnel and equipment to gain access to another property where an investigation is to be conducted. Property belonging to other government bodies, agencies, or institutions, and highway property which is not part of the public road system are also included in this restriction.

The District Geologist or other person in charge of the investigation is to ascertain that all property owners have been notified and that permission to conduct the investigation has been granted prior to the commencement of the work. The owner should be advised of the nature and extent of the investigation and provided with the name and telephone number of the person to be notified, usually the District Materials Engineer, in case problems or additional questions arise. Any legitimate questions which cannot be answered by the Geologist or other person in charge at the time of notification of the property owner should be referred to the District Materials Engineer, and a prompt response should be given. This need not interfere with the commencement of the investigation, unless permission to enter is denied until a response is received.

The owners should also be advised that a follow-up inspection will be made by the District Materials Section approximately 30 days after the initial survey, for the purpose of inspecting drill holes and filling any that have settled. In all cases when property has been damaged or is likely to be damaged by the drill crew and equipment, the person in charge of the crew should attempt to contact the property owner immediately and explain that a Department representative will be in contact to make adjustments for the damage. Appraisals of the amount of damage and arrangements for the actual payment of assessed value of such damage will be handled by the Right-of-Way Division. At the discretion of the Geologist, it might be advisable to photograph the property before commencing field work.

In any case where the property owner refuses to allow the drilling crew permission to make the necessary exploration, the Geologist is to avoid an argument, and will immediately request the District Materials Engineer to visit the property owner in an effort to secure permission. If the District Materials Engineer is unsuccessful in securing the permission, the matter is then to be handled in a manner prescribed by the Department.

Whenever a job requires entry onto railroad property, a working arrangement has been established with the railroad companies in Virginia through the Central Office Rail and Public Transportation Division's Division Assistant Administrator. In this case, the District Geologist is to write to the Rail and Public Transportation Division (DRPT) Assistant Administrator requesting that arrangements be made for permission to enter. A copy of the letter should be sent to the office of the Assistant Administrative Services Officer, who will arrange for the insurance. Two (2) copies of the situation plans showing the location of the borings are to be forwarded with the letter of request, which shall include the following information:

(1) Name of the railroad.

(2) Lateral limits of the job, with respect to the nearest railroad milepost, and location of abutments and/or piers with relation to tracks.

(3) Project Number.

(4) Special requirements; such as, flagperson, train schedule, etc.

(5) Estimated date drilling will start.

(6) Estimated date drilling will end.

The Rail and Public Transportation Division Assistant Administrator and the Assistant Administrative Services Officer must be notified if a time extension is required.

The DRPT may request estimated cost of all drilling operations performed on the railroad right-of-way, and the type of equipment to be used.

Sec. 303.03 Staking the Line

The proposed lines (or boring locations) should be staked before an Investigation is started. This is the responsibility of the District Survey Party Supervisor who should also notify the District Materials Engineer promptly in the event of an alignment change.

Sec. 303.04 Preliminary Field Inspection / Inspection of the Site

The majority of the District Geologist's investigations will be part of the preliminary engineering study, however, during the preliminary field inspection stage of the investigation, it is possible to recommend alternate locations of structures, potential borrow sites, alignment changes to avoid unsatisfactory geologic conditions, etc.

Sec. 303.05 Location of Drill Holes

Normally the site will have been visited by the Geologist or the Materials Technician Supervisor in charge of Preliminary Engineering, who has noted the absence or presence of survey centerline stakes, (or boring location stakes), location of bench marks, and on-site availability of water. Before the driller sets up the equipment, the Geologist or Supervisor in charge of Preliminary Engineering should, confirm the boring location, and if practical determine the elevation of the top of each hole. This determination may require assistance from the survey party.

SECTION 304 SOIL SURVEY

Sec. 304.01 General

Prior to any new construction, whether on a new location or in the rebuilding of an existing road, it is necessary to make and complete a detailed soil survey. Conditions will vary according to locality. While the procedure outlined below is the minimum requirement for primary highway standards, the same procedure may be used on the interstate and secondary systems, if modified by respectively increasing or reducing the number of borings. Soil surveys should be conducted generally in accordance with AASHTO R13, with the herein specified minimum requirements. See Sec. 207 and Sec. 208 for a list of Special Projects not requiring soil surveys.

Sec. 304.02 Initial Preliminary Survey

Prior to a final and complete soil survey, a preliminary soil investigation is to be made, consisting of a ground inspection of the proposed alignment. If the soils data is available from former surveys, full use should be made of it. Any report that originates from the District Materials Section should be based on experience, the best judgment possible, and a very minimum boring program, if necessary. At most, one boring should be made to refusal at bedrock, or a maximum of 5 ft. (1.5 m) below anticipated grade in cut sections 10 ft. (3 m) or more in depth.

There will be some variation among Districts as to the purpose of preliminary information. Each District should list its own specific problems in the report. The time needed to accomplish this investigation should be from one to three days only.

Sec. 304.03 Final Soil Survey

The detailed soil survey will be requested only after the line has been approved by the Location and Design Division. Under normal circumstances, borings should be drilled to a depth of 5 ft (1.5 m) below proposed grade at intervals of 200 ft. (60 m). For divided highways, borings should be drilled in a staggered pattern, maintaining the 200 ft. (60 m) interval in each lane. In areas of fill embankment exceeding 5 ft. (1.5 m) in height, borings can be eliminated unless the ground is perceived to have potential stability, settlement or consolidation problems. On very rough terrain that is inaccessible for drilling equipment, geophysical methods or geological traversing, including trenching should be used to locate the rock.

(a) Rock

On sections where independent grading is required (or where the median is not graded) in cuts containing rock of undetermined persistence or quality, 4 points must be drilled on cross sections at 100 ft. (40 m) intervals along the mainline on each lane. The points in each lane are one in each ditch line and one on each cut slope at a distance halfway between the ditch point and where the designed slope reaches the ground (cut slope tie-in).

On sections where dependent grading is required (or where the median is graded out) in rock cuts, 2 points must be drilled on each lane and one in the center of the median, at cross sections along the mainline at 100 ft. (40 m) intervals. The points on each lane are one at the outside ditch and one on the cut slope at a distance halfway between the outside ditch point and where the designed slope reaches the ground (cut slope tie-in).

All points mentioned above should be drilled to a depth of 5 ft. (1.5 m) below the finished grade, unless solid rock is first encountered. The points on the cut slopes should be drilled to a depth that will intersect the designed cut slope unless solid rock is first encountered.

On service roads, connections, ramps, and loops, borings should be made on the centerline at 100 ft. (60 m) intervals in cut sections where rock is encountered.*

(b) Soil Cuts

On sections where independent grading is required, one point must be drilled at 200 ft. (60 m) intervals on each lane. The point on each lane is at the centerline of the uphill ditch. If saturated or unsuitable material is encountered, borings should be made at 100 ft. (30 m) intervals on each ditch line.*

On sections where dependent grading is required, the points must be drilled at 200 ft. (60 m) intervals*. These points are located on the outside ditch of each lane and at the center of the median. If saturated or unsuitable material is encountered, borings should be made at 100 ft. (30 m) intervals on the same points on the cross-section as outlined above.*

*All points mentioned above should be drilled at least 5 ft. (1.5 m) below finished grade.

Samples weighing approximately 50 lbs. (25 kg) each of the different types of soil found in the cuts should be taken from the borings for laboratory tests. Samples weighing approximately 100 grams should be taken at 5 ft. (1.5 m) intervals, especially when the soil appears wet or above optimum moisture, and especially at subgrade elevation for determination of field moisture content. The field moisture is essential in estimating the quantity of unsuitable material found on the project. Also, the limits of different soils should be established as accurately as possible.

Fill slope areas within a roadway widening should be investigated to determine the need for undercut if they were used as waste areas for unsuitable materials.

* In the event that the materials or geological conditions found in adjacent borings differ greatly, an intermediate boring or borings may be necessary to characterize the situation accurately.

All holes should be refilled and the top 5 ft. (1.5 m) tamped well. It is preferable to place a small stone over the hole. The District Materials Engineer should designate someone to return to the survey site approximately 30 days after the survey to inspect drill holes, and to properly fill those that have settled to such an extent as to cause possible problems (See Sec. 303.02).

(c) Duties of Geology Section

After the soil overburden has been investigated, the geology section will investigate and recommend slopes in the bedrock. A rock slope stability analysis should be completed if the Geologist can determine the attitude of rock discontinuities. If bedrock is not visible and oriented cores are not available, a rock slope stability analysis should be requested to occur during construction, as bedrock is exposed, to determine if the slope angles are correct and if construction activities may be completed safely. A geophysical survey may be prepared concurrently with the soil survey. The soundings will alternate with the boring location. Core borings will be taken in the deeper cuts in order to define the character of the rock. These boring locations will be determined by the results of the geophysical and soil surveys. The borings may be maintained as groundwater monitoring wells. In addition to the analysis of the boring logs, a geological reconnaissance will be made noting angles of repose of the overburden, strikes and dips, etc. A study will be made of present cuts in the material to determine the effects of weather on the slopes. The rock cores may be subjected to a physical test that would indicate the approximate time that a slope might stand under normal freeze-thaw conditions.

(d) Sampling Select Material

When it is determined during the soil survey that material available on the job site is suitable for use as select material, samples of the soil may be requested from the proposed site for laboratory testing. Care should be exercised to ensure that the samples are representative of the material available. To obtain samples, test holes should be drilled at randomly selected locations within the site. The number of test holes will be determined by local conditions, such as areal extent and depth of deposit to be evaluated. All samples taken should be submitted to the District Materials Laboratory for analysis. If the material is to be used for strengthening weak sections of the road, enough material should be submitted to the District Materials Laboratory to run C.B.R. tests.

(e) Waste and Borrow Material

Disposal of waste and/or surplus material and the location and control of borrow pit sites normally will be the responsibility of the contractor.

Whatever data is available as to the quantities involved will be furnished by the Location and Design Division along with the usual line and grade. When surplus material does occur, it should be tested to determine if the material can be used in the roadway, or, if sufficient areas cannot be located within the right-of-way, it is to be disposed of outside the right-of-way as unsuitable material.

The District Materials Engineer may locate and investigate possible sites for local materials. He will take sufficient borings and conduct tests on the material to make certain that it is suitable for the purpose intended, and to make sure that a sufficient quantity of material has been located. Data concerning the borrow pit should include the shrinkage estimate, in order to aid in properly evaluating available quantities. At the completion of his investigation, the District Materials Engineer will draw a sketch of the area or areas giving the approximate boundaries. Distances may be approximated. After the boundaries of the site have been located, they should be referenced to some geographical feature, such as a road intersection or other similar feature.

Following such an investigation by the District Materials Engineer, he/she will request the District Right-of-Way Manager to obtain an option on the property where the pit site is located. A copy of the request should be sent to the Right-of-Way Division Administrator and the

Materials Division Administrator. The sketch prepared by the District Materials Engineer should accompany the request. Since changes in design are frequent, it is essential that close and constant coordination during plan development be maintained among the Location and Design, Right-of-Way, and Materials Divisions.

After the contract for construction has been awarded, the Contractor may desire to use local material from sources other than what might be located or furnished by the Department. Should the Contractor choose to locate his/her own sources of local material, the procedure outlined in Sec. 106.03(b) of the Road and Bridge specifications must be followed.

(f) Channel Change and Embankment Riprap Location

A soil survey is to be conducted through areas where a channel change is proposed and through embankment areas where riprap may be required. The profile sheet of the plans used for the regular soil survey will show the location of channel changes and the location where riprap will be required on the fill section. Borings along the proposed channel change are to be taken at sufficient intervals to determine the type of material encountered along the slopes and in the bottom of the channel. The borings made in the cut sections or in the borrow pits for the construction of these fills are adequate to determine the type of material used in the fills. This information should be submitted in the regular soil survey report.

(g) Summary of Soil Survey

It is the District Engineer's responsibility to see that all the information necessary for completion of road plans is obtained and submitted at approximately the same time. In areas where geophysical data is necessary to determine the thickness of overburden and where slope design recommendations are required, this data is just as essential to the completion of the road plans as the soil survey and pavement design recommendations. Therefore it is necessary that every effort be made to correlate the simultaneous securing of all necessary data and submission of all relative reports and recommendations. Upon completion of the soil survey, the District Materials Engineer shall prepare a complete report, together with laboratory test reports, with distribution as outlined in Sec. 800. The objectives of the soil survey and the information to be contained in the survey report are as follows:

(1) Obtain representative samples of soil for necessary tests.

(2) Determine and define the limits represented by those samples, both horizontal and vertical.

(3) Determine the depth to rock, if within the limits of the exploration.

(4) Determine whether or not underground water is present and the depth at which encountered. Obtain samples for the determination of soil moisture content, so that the percent of moisture present can be compared with the optimum moisture content of the same material.

(5) Investigate fill sections for evidence of soft or swampy conditions. If such conditions exist, determine the depth of the unsuitable material and take undisturbed samples for evaluation of stability and load carrying capacity. Submit specific recommendations for constructing embankments over the area, including depths of undercut, location of undercut (by stations), and disposition of undercut material.

(6) Show "shrinkage and swell estimates" by section, "root mat depths and extent", and "cut slopes", if different than originally called for on plans.

(7) Keep a complete and detailed set of field notes to be submitted as part of the soil survey report.

(8) Report the length of project, either in feet (meters) or miles (kilometers), and include the station numbers of the project limits.

(9) Show the type, depth, width, and composition of the existing pavements along the survey line, if line is along the existing road. Include the mainline, adjoining sections of mainline, and all connections to the mainline project. Report should indicate whether or not the project is one of new construction, utilization of existing pavements, widening, parallel dual lane construction, curb and gutter, and/or resurfacing of existing pavement. Recommendations should include the present condition of any existing pavements, together with recommendations for salvage or construction of new pavement. If the soil survey is for a secondary pavement design, show the latest average daily traffic and the traffic anticipated 10 years hence, if this data is available.

(10) Make specific slope recommendations and submit to Central Office Materials Division for review and concurrence (See also Item 6).

(11) List the anticipated source of select material, if used, as being either local or commercial. Show the unit dry weight (compacted in place) in pounds per cubic foot (kg/m^3), for the aggregate base, subbase, or select material that is anticipated to be used. This normally averages between 140 and 150 lbs. per cu. ft. (2240 to 2400 kg/m^3) for commercial granular materials and somewhat less for pit materials.

(12) Make recommendations for location and amount of underdrain if needed, and recommendations relevant to stormwater management basins.

(13) Show any other miscellaneous field information that is pertinent to soil survey and pavement design.

(14) Submit to the Central Soils Laboratory a set of plans showing the location of rock, field moisture of soil, and show in color on the soil profile sheets the length and depth of the area where saturated material is encountered and sufficient information to support the conclusions and recommendations.

In order to adhere to project advertisement schedules, it is generally necessary that soil surveys be completed by the completion target date established in the Project/Program Monitoring System (P/PMS) schedule for each project. In some cases, it may be necessary for the District to request assistance to complete the soil surveys by the originally scheduled target dates. If such a need arises, the District Materials Engineer should follow the procedure for requesting assistance outlined in Sec. 303.01 herein.

SECTION 305 INVESTIGATION OF SOILS FOR FOUNDATION DESIGN

Sec. 305.01 General

The satisfactory performance of any foundation depends upon the quality and completeness of the information upon which its design is based. The acquisition of information relating to the materials which will support or constitute the foundation is, therefore, the most important objective of the foundation investigation. Information which is not already available in the form of geological and soil survey publications, maps, files, and previous reports must be obtained by drill crews directly from the site. The importance of obtaining accurate foundation data is reflected in the amount of effort and investment in terms of manpower and equipment that is directed towards this end.

Soil is defined in AASHTO M146 as "sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter. The Classification of soils in the field is usually limited to a description of characteristics that may be observed during the process of making the explorations. This includes a description of the soil components, including water content and the relative abundance of each component, and physical characteristics, such as compactness, density, plasticity, and color. Most natural soils consist of a mixture of two or more of the following constituents: gravel, sand, silt, clay, and organic matter. For field classification, soil is given the name of the predominant type with the lesser portions as adjectives. For example, a sandy silty clay consists mainly of clay with lesser amounts of silt and sand. Care must be taken to classify correctly material that has been comminuted by boring processes.

During the field investigation, any additional comments should be noted, such as the presence of roots or root holes, presence of mica, gypsum, surface coating on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in excavating, etc.

(a) Subsurface Investigation for Minor Structures:

Pipe and Culvert Foundations: ** At the request of the Location and Design Division, a foundation investigation will be performed for all culvert installations with diameters of 36” (900 mm) or greater. The foundation shall be explored below the bottom of the excavation to determine the type and condition of material present. The pH and resistivity of the in situ soils will be provided in the evaluation where corrugated metal pipe is specified. The required soil sample shall be of approximately 5000 grams (11#). Foundation data may be provided for culverts that are less than 36” (900 mm) diameter if deemed necessary.

A stability index must be determined on water of live streams that will come in contact with drainage structures. The water samples must be taken on the same day that they are to be tested. Two, 500-milliliter (1 pint) samples shall be taken per test.

The locations where foundation investigation is required will be determined from plans provided by the Location and Design Division at the time of request.

Stormwater Management Basins: The following section addresses the need for preliminary soils investigations for stormwater management basins that are required to protect the properties and waterways downstream from erosion due to increases in the volume, velocity, and peak flow of stormwater runoff. Unless otherwise noted, it shall be assumed that all basins are dry basins with no permanently ponding water.

The Location and Design Division shall provide the Materials Division with detailed plans outlining the proposed locations of stormwater management basins (SWM) in conjunction with their request for subsurface investigation for minor structures. This information is requested under Program Project Management System code #40. Stormwater management basins shall be included in the subsurface investigation for minor structures.. The tracking and reporting of this investigation shall be included under the PPMS activity code #45. A minimum of two borings shall be taken per basin, one from the site of the proposed dam foundation and one from the area to be excavated for the retention basin. One additional boring shall be taken for each additional acre (0.5 hectare) of ponding area greater than two acres (1 hectare). Borings shall not exceed a depth of two meters (six feet) below the plan bottom where bedrock is not encountered and shall be terminated at bedrock if it is encountered. The following parameters shall be determined from the investigation.

(1) **Soil Classification:** To aid in determining the suitability of the naturally occurring soils for use in dam construction or for use as fill material in roadway embankment, all index tests are to be performed. CBR values shall be provided if the materials are to be included in roadway embankment as fill material.

(2) **Ground Water Table:** Establishing the relative proximity of the bottom of the retention basin to the groundwater table is critical in determining the design of the basin.

(3) **Depth of Bedrock:** The presence of near-surface bedrock in the excavation of the retention basin may justify the site of the basin to be revised.

The District Materials Engineer shall prepare a report, that should include recommendations for suitability of excavated materials as embankment, potential corrosion of pipes/minor structures and any special recommendations pertaining to the above items. The report shall be submitted to the State Materials Engineer.

Sec. 305.02 Field Classification of Soils

In the field, a representative sample of soil is visually examined and is first classified as to whether it is highly organic, fine-grained, or coarse-grained. This classification for fineness and coarseness is made by estimating whether or not one half of the individual grains can be seen, with the naked eye. If 50 percent or more of the particles can be seen, the soil is classified as coarse-grained; otherwise, the soil is classified as fine-grained.

(a) Sand and Gravel

If the soil is coarse-grained, it is classified as gravel or sand, depending upon whether or not 50 percent of the coarse grains are larger or smaller than the openings in a No. 10 (2.00 mm) sieve.

(1) Gravel

Particles of rock that will pass a 3 inch (75 mm) sieve and be retained on a No. 10 (2.00 mm) sieve with the following subdivisions:

Coarse - Particles of rock that will pass a 3 inch (75 mm) sieve and retained on 3/4 inch (19.0 mm) sieve.

Fine - Passes 3/4 inch (19.0 mm) sieve and retained on No. 10 (2.00 mm) sieve.

(2) Sand

Particles of rock that will pass a No. 10 (2.00 mm) sieve and be retained on a No. 200 (75 μm) sieve with the following subdivisions:

Coarse - Passes No. 10 (2.00 mm) sieve and retained on No. 40 (425 μm) sieve.

Fine - Passes No. 40 (425 μm) sieve and retained on No. 200 (75 μm) sieve.

<u>(b) Silt/Clay Soils</u>

(1) Silt

Soil passing a No. 200 (75 µm) sieve and that is nonplastic or very slightly plastic, and that exhibits little or no strength when air dried.

(2) Clay

Soil passing a No. 200 (75 µm) sieve and that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air dried.

<u>(c) Organic Soils</u>

These soils are identified by color, odor, and spongy feel, and frequently by a fibrous texture. Organic matter is often indicated by the presence of olive green and light brown to black colors. Organic soils usually emit a distinctive odor of decaying vegetation.

(1) Organic Clay

A clay with sufficient organic content to influence the soil properties.

(2) Organic Silt

A silt with sufficient organic content to influence the soil properties.

(3) Peat

A soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

<u>(d) Density and Compactness</u>

The density of a soil is defined as the mass per unit volume of the soil - a laboratory test. Density of a soil is variable depending on its mineral and rock particle densities, moisture content, and natural or artificial compaction. Natural compaction - compactness - is a field condition of in situ or undisturbed soil. Compactness is defined by the number of hammer blows from the Standard Penetration Test. The compactness of material estimated or described as follows:

(1) Compactness of Coarse-Grained Soils

Term	**Remarks**	**Blows/foot (0.3 m)**
Loose	Sand or sand and gravel which can be excavated by a shovel is considered to be loose.	10 or less
Firm	Sand or sand and gravel which can be excavated with a shovel.	11 - 30
Compact	Sand or sand and gravel which require the use of a pick for its removal is considered to be compact.	31 - 50

Very Compact	Sand or sand and gravel which requires the use of a pick, but with effort.	51 or more

(2) Compactness of Fine-Grained Soils

Term	**Remarks**	**Blows/foot (0.3 m)**
Very Soft	Easily penetrated several centimeters by fist.	Push to 1
Soft	Easily penetrated several centimeters by thumb.	2 - 4
Medium	Can be penetrated several centimeters by thumb with moderate effort.	5 - 8
Stiff	Readily indented by thumb, but penetrated only with a great effort.	9-30
Hard	Difficult to indent with thumbnail.	31 or more

The density of coarse-grained soils and the consistency of fine-grained soils is determined by the Standard Penetration Test performed in test borings. The number of blows of a 140 lb. (63.5 kg) hammer falling 30 in. (0.76 m) required to drive a 2 in. (51 mm) O. D. split spoon sampler into virgin soil is recorded for each 6 in. (0.15 m) of penetration for a total penetration of at least 18 in. (0.45 m). The blow count for the first 6 in. (0.15 m) is ignored, but the blow counts for the succeeding two (2)-6 in. (0.15 m) increments are added to obtain the N value (blows per foot (0.3 m) of penetration). All three blow counts should be recorded separately. When the blow count for a 6 inch (0.15 m) interval reaches 50, the penetration depth is to be recorded to the nearest 0.1 foot (0.03 m).

(e) Proportions of Components

The primary soil constituent is to be determined on the basis of the grain size and plasticity characteristics. Secondary soil constituents should be determined also on the basis of gradation and plasticity. The following chart shows the term to be used describing the proportion of a component:

TERM	PROPORTION
and	35-50%
some	20-35%
little	10-20%
trace	up to 10%

(f) Color

The color of any soil is often of value in correlating samples. Standard colors, with such modifying colors as are necessary for a full description, are to be used, such as blue, brown, gray, bluish gray, mottled brown and gray, etc. Special investigations may require that color is accurately identified by reference to the Munsell® Soil Color Charts.

Organic soils are generally dark and drab. The shades of gray and black generally indicate various proportions of organic matter. The color is descriptive of the fresh sample as it comes out of the ground. If the color represents a dry condition, this shall be stated in the report. If the sample contains layers or patches of varying colors, this shall be noted and all colors described.

(g) Moisture Content

Dry - Absence of moisture, dusty, dry to the touch.

Moist - Damp, but no visible water.

Wet- Visible free water, usually soil is below water table.

(h) Plasticity

Plasticity may be defined as the capacity of a material to withstand changes of form under the action of constant forces without any appreciable breakage or volume change. It owes its characteristics primarily to the small size of its true clay materials. By adding water to this material, it may be transformed into a plastic mass and, when dried completely, it forms a hard material which cannot be crushed into individual grains by finger pressure.

Silt/Clay Soils - Classified by Plasticity

Inorganic	Organic	Plasticity
silt	organic silt (non plastic)	none
clayey silt	organic silt (slight P.I.)	slight
silt & clay	organic silt (low P.I.)	low
clay & silt	organic silt (medium P.I.)	medium
silty clay	organic silt (high P.I.)	high
clay	organic silt (very high P.I.)	very high

(i) Cementation

The cementation of intact coarse-grained soil can be described as follows:

Weak - Crumbles or breaks with handling or little finger pressure.

Moderate - Crumbles or breaks with considerable finger pressure.

Strong - Will not crumble or break with finger pressure.

Sec. 305.03 Cased Borings

Where hollow-flight auger equipment cannot be used, cased borings will be made by driving pipe casing and removing the soil within the casing by washing. Casings shall be sunk vertically through earth and other materials, including boulders and rock veins, to rock, or to such depth below ground as directed. The casing shall be extra strong pipe with nominal inside diameter of 2 ½ (63 mm) or 4 inches (102 mm). It shall be driven without washing to the depth at which a sample is to be taken, after which the material shall be cleared out to the bottom of the casing. A sample should always be taken in the first 5 ft. (1.5 m) of any boring by the methods hereinafter described, and at 5 ft. (1.5) intervals or at change of stratum thereafter.

If casing is to be driven, the use of clean water for cleaning out the casing between sample excavations will be required. A continuous record of the blows per foot (0.3 m) required for the driving of the casing will be kept by the operator, when necessary. The weight of the hammer used in driving the casing and the height of free fall shall be recorded.

Simultaneous washing and driving of the casing will not be permitted, except in the case of difficult driving which requires the use of water. Where such use of water is permitted, a record must be kept by the Geologist of the elevations between which simultaneous washing and driving occurred. In some cases of very difficult driving and where the characteristics of the soil are suitable, permission may be given to discontinue driving the casing and proceed with the boring. Should there be an indication of the sides of the hole collapsing, thus blocking normal progress of the boring, driving of the casing shall be resumed as described above.

Sec. 305.04 Ordinary Dry Samples (Standard Penetration Test)

Except where undisturbed dry samples are ordered, ordinary dry samples shall be taken at every change in soil formation, and between soil changes, at vertical intervals not exceeding 5 ft. (1.5 m). In some cases of thinly stratified formations, it may be necessary to take continuous samples, in order to establish all the various changes in the soil profile. Ordinary dry samples shall be taken with a split-barrel sampler. The inside diameter of the sampler shoe shall be 1 3/8 in. (35 mm), the outside diameter 2 in.(51 mm), and of sufficient length to take a continuous 2 ft. (0.6 m) sample. No sampler shall be used which does not have a split barrel for the entire length of sample or which does not contain a ball valve, or whose sampler shoe is damaged. Ordinary dry samples shall be obtained by driving the sampler not less than 1 1/2 ft. (0.5 m) into the material below the bottom of the cleaned casing, if casing is used. If a sample is not obtained in this 2 ft. (0.6 m) of penetration, the sampler shall be driven again for an additional foot (0.3 m) of penetration. Should the material be so incohesive that this second attempt fails to secure a sample, a trap valve should be inserted in the shoe of the sampler and the sampler driven an additional foot (0.3 m). Should this last procedure fail to secure a sample, an auger or sand-trap should be used until the required sample is obtained.

A record of the number of blows required to drive the sampler for each 6 inches (150 mm) of penetration will be kept. A description of the sample obtained for each foot (0.3 m) of penetration will also be recorded by the Geologist, but only a representative sample, unless otherwise directed, shall be preserved in a jar as specified below. To facilitate determination of the relative resistance's of the various strata, the sampler shall always be driven with a 140 lb. (63.5 kg) hammer with a free fall of 30 in (0.76 m).

All ordinary dry samples, immediately upon removal from the sampler, shall be placed and tightly sealed in clear glass jars with screw caps. Each sample should be of sufficient size to fill the jar, and shall be placed in the jar carefully and in its correct position to represent as nearly as possible its natural condition. Each jar shall be clearly labeled showing the number of the project, boring and sample numbers, elevations between which the sample was taken, and number of blows on the sampler for each 6 inches (0.3 m) of penetration.

The operator should keep a sufficient supply of glass jars on hand to prevent any delay in the work and shall carefully preserve and deliver the samples as specified in Sec. 309 herein.

Sec. 305.05 Undisturbed Dry Samples

At selected locations in strata of soft clay, organic silt, and cohesive materials of questionable stability, undisturbed dry samples, such as Shelby Tube samples will be required. The object is to obtain samples of the soil formation which have been subjected to a minimum of disturbance and which represent, as truly as may be obtained, the actual condition of the soil in its natural state.

Undisturbed dry samples in the above mentioned strata shall be taken as directed. In certain cases where the depth of such strata warrants, continuous samples of this type will be required.

When preparing to take an undisturbed sample, all loose and disturbed material shall be removed to the bottom of the casing. Cleaning out shall be done in such a manner that the soil immediately below the bottom of the casing will be as nearly undisturbed as possible. The sampler shall then be lowered slowly to the bottom of the casing, and pressed by hydraulic action into the soil a distance sufficient to fill the sampler to within 3 or 4 in.(75 to 100 mm) of its capacity. When using the piston type, or Shelby sampler, the piston should be set flush with the cutting edge at the bottom, and carefully lowered to rest on the soil at the bottom of the casing. The rod supporting the piston shall then be clamped to the top of the casing of the drill derrick so as to be immovable, after which the sampling tube shall be forced down as previously described to the proper depth. Then, the two rods shall be locked together at the top and the entire assembly slowly withdrawn from the hole, as described below.

After the sampler has penetrated the required depth, allow 10 minutes and then give a slow twist to shear the soil. It should then be carefully removed from the hole and the tube section containing the soil sample detached. The bottom of the sample shall be carefully squared up no less than 1/2 in. (13 mm) beyond the end. Both ends of the tube shall be completely filled with hot paraffin. The tubes shall then be closed at both ends with snug fitting caps, which are to be secured in place with friction tape, after which the ends of the tube shall be dipped in hot paraffin to provide air-tight seals.

Undisturbed dry samples must be clearly labeled showing the description of the project, project number, boring number, sample number, and elevations between which the sample was taken. Special care should be taken to indicate the top end of the sample tube. The tubes should be kept in the correct vertical orientation during shipping and storage.

The Geologist or operator will carefully preserve these samples and deliver them to the testing laboratory as soon as possible, so that they can be stored in a moisture room. Extreme care must be taken in handling undisturbed samples to avoid shock or jarring which may affect the character of the material. (See Sec. 308 herein.)

Sec. 305.06 Vane Shear Test

The field vane shear test attempts to directly measure the in-situ undrained shear strength of fine-grained, cohesive soils. Specific details of the test are in ASTM D-2573.

The test consists of advancing a four-bladed vane to a desired soil depth and measuring the applied torque as the vane is rotated at a constant rate. Shearing resistance is considered to be mobilized on a cylindrical failure surface corresponding to the top, bottom, and sides of the vane assembly. The preferred vane shape is a rectangular four-bladed vane with a height/diameter ratio of two.

It is important that the soil in which the vane shear test is done is well characterized, including information on the presence of roots, shells, sand lenses, and varves, since these may lead to an over-estimation of the strength of the soil.

Sec. 305.07 Cone Penetrometer Test

The cone penetrometer test consists of pushing a series of cylindrical rods with a cone at the base into the soil at a constant rate of 2 cm/sec. Continuous measurements of penetration resistance on the cone tip and friction on a friction sleeve are recorded during penetration. A Piezo-cone records pore pressures in addition to point and friction resistance.

The continuous profiles obtained with the cone penetrometer test allow the user to visualize the stratigraphy, to evaluate the soil type, to estimate a large number of fundamental soil parameters, and to directly design shallow and deep foundations subjected to vertical loads.

Sec. 305.08 Flat Dilatometer Test

A dilatometer test consists of pushing a flat blade located at the end of a series of rods. Once at the testing depth, a circular steel membrane located on one side of the blade is expanded horizontally into the soil. The pressure is recorded at three specific moments during the test. The blade is then advanced to the next testing depth.

The design applications of the dilatometer test include: deep foundations under horizontal and vertical load, shallow foundations under vertical load, and compaction control.

Sec. 305.09 –Scour Investigation

Samples representing the predominant soil types shall be taken from each proposed bridge site. The sample shall be submitted to the Central Office Materials Soil Mechanics Laboratory for particle size analysis testing. Samples shall be gathered from the split-barrel sampler used to perform the Standard Penetration Test or from the auger cuttings, or other appropriate means. If core or auger samples are not possible at the actual pier locations, then the samples shall be taken as close as possible to the pier locations. The results of such test shall be submitted to the District Geologist and forwarded to the Hydraulics Section of the Central Office Location & Design Division.

Sampling for Scour: Test samples shall be taken from bore holes at streambed elevation downward to a depth of twenty feet (6 m) below the existing streambed or bedrock. In the coastal plain region, samples shall be taken to a depth of twenty feet (6 m) below the existing streambed elevation.

Sample Size: The minimum amount of material required for the scour sample should not be less than the amount shown in the following table. However, if there is larger top size material than shown in the chart below, the material must be included in the sample that is gathered to represent the strata from which it was taken. The overall sample size shall be increased proportionally, but the maximum sample size shall not exceed 50 pounds (25 kg) .

NOMINAL SIZE OF LARGEST PARTICLES STANDARD (Alternative)		***APPROXIMATE MINIMUM WEIGHT OF SAMPLE***	
mm	***in***	***kg***	***lb***
9.5	***3/8***	***0.5***	***1***
25	***1***	***2***	***5***
50	***2***	***4***	***9***
75	***3***	***5***	***11***

SECTION 306 BEDROCK INVESTIGATIONS

Sec. 306.01 General

Diamond drill cores are obtained to gather information on the nature and condition of the bedrock for the design of rock cut slopes, foundations, and occasionally for aggregate studies. A continuous sample of the rock core is the ideal that is seldom attained, as soft or broken portions of a formation are easily ground up or eroded by the drill water during the coring operation. Unfortunately, the material that is lost has the greatest significance in determining the overall integrity of the rock. Therefore, every effort should be made to observe and record as much information as possible on zones of lost or damaged rock core. A careful study of the record, together with a close examination of the portion of the cores recovered, will provide clues to the nature of the material lost.

Sec. 306.02 Rock Classification

Classification of the rock types found on the project should be done by the Geologist during the initial stages of the investigation. Uniform descriptions should be used throughout the investigation and should include whatever qualifying terms are necessary to fully describe the condition of the rock.

The following information should be included:

(a) Classification of Rock Type - Igneous, Metamorphic, or Sedimentary

(b) Identification of Rock Variety - shale, schist, slate, limestone, granite, dolomite, basalt, etc.

(c) Formation Name.

(d) Condition - Massive, thick bedded, or thin bedded; fractured, faulted, or jointed; fresh, weathered, or decomposed, etc.

(e) Relative Hardness.

(f) Attitude - Strike and dip of bedding and discontinuities.

The crew chief or driller may be the only source of information relating to the drilling and related characteristics of the rock, and should record this information as it occurs during the coring run to avoid its loss. All data should be recorded chronologically as it is observed, and under no circumstance should this be put off until after the core is pulled.

Sec. 306.03 Coring Equipment

Drilling is to be done with standard core drilling equipment of the fluid flush, rotary type with hydraulic feed, equipped usually with a double tube core barrel and a diamond bit capable of producing cores with a minimum diameter of 1 1/8 in. (29 mm) (AX); where Rock Quality Designation values (RQD) are to be determined, the minimum rock core diameter shall be 2 1/8 in. (55 mm) (NX). Split double and triple tube core barrels may be used to enhance recovery, and tungsten carbide core bits may be satisfactory on some softer formations. Wireline equipment is recommended for difficult drilling conditions. The circulating fluid is generally water, but drilling mud also may be used.

Sec. 306.04 Procedure

(a) General

All measurements of drilling depth should be made by determining the "stick-up" of the drill rods, which is the distance from top of ground to the bottom of the hydraulic swivel attached to the top of the drill rods. Measurements to a tenth of a foot (25 mm) are usually of sufficient accuracy. The length of the core barrel and bit, as well as the shoulder-to-shoulder length of the drill rods, should be measured before they are made up into the string of tools, so that the "stick-up" subtracted from the length of the tools will give the depth of the bit in the hole. As the depth of the hole increases, rods should be taken individually from the pile of reserve rods and placed in the string of drill rods. Even though it is usually necessary to have the elevation of the hole determined in advance of the drilling, it is seldom necessary to record all drilling data by means of both depth and elevation. The Geologist will have much less opportunity for error if the records are in depths only, and show only the elevation of the top of the hole. The important elevations, such as those of the top of the rock, the water table, etc., can be added when the field log of the hole is prepared. The name of the driller should be entered in the record or log of the hole.

(b) Rig Setup

Before beginning coring, the driller should ensure that the drill is mounted on a stable base or platform and that the drill rods are in as vertical a position as possible. The drill head should be secure and free from eccentricity when the spindle is rotating. Drill rods should be checked for straightness and any bent rods discarded. The core barrel should be inspected to ensure that the inner barrel is rotating freely, and the bit should be checked for excessive wear.

(c) Drilling in Overburden

If the overburden is penetrated by the use of a "fishtail" or roller bit, the return drill water should be watched for changes in color and samples of the wash material taken from time to time. Particular attention should be paid to details whenever a change in the color of the water occurs or a change in the drill response is noted. Clay, silt, sand, gravel, and boulder horizons can all be determined and recorded when drilling with a "fishtail" or roller bit, although not as accurately as by drive sampling.

Depth measurements should be made in accordance with the instructions in Paragraph (a) above.

(d) Core Drilling

Before starting the core barrel in the hole, a suitable technique shall be used to break up and clear all disintegrated rock and casing seated firmly on hard rock if necessary.

The core bit shall be started in the hole and drilled for a maximum depth of 5 ft. (1.5 m). The drill bit shall then be removed and the core withdrawn from the barrel, labeled, and stored as outlined in Sec. 308 herein. When drilling in igneous and metamorphic rocks, a run of 5 ft. (1.5 m) into solid rock shall be made, in order to detect any clay seams or zones of disintegration; in sedimentary rocks, particularly in limestone and dolomite, a run of 10 ft. (3 m) shall be made into solid rock, in order to detect clay seams, solution channels, or cavities. If the core bit should become blocked by a piece of broken core, the barrel should be cleared before continuing the drilling.

Particular attention should be paid to the drilling characteristics and the circulation returns, so that probable reasons for any core losses can be given. Core losses are most apt to occur when drilling through weathered or fractured rock, or through alternate hard and soft layers such as interbedded sandstone and shale. Core losses can often be located within the pull if close records of the drilling operation have been kept. For example, shale beds a few inches (mm) in thickness interbedded with sandstone or limestone, and thin clay seams or gouge layers, are frequently ground or washed away, and the only indication of their presence may be a momentary discoloration of the return water accompanied by a period of smoother drilling. If core losses are serious in such cases, the percentage lost can be reduced by making a pull each time the bit encounters a new type of material. This reduces the amount of prodction length drilled per day, but it increases the percentage of core recovery, which is the primary concern.

Core losses are also caused by the use of improper drilling procedure. The proper drilling speed, water pressure, drill pressure, etc., all have to be determined on the job by experimentation. It is good practice never to make a run equal to the full length of the core barrel, since certain types of rock have a tendency to swell from pressure release or wetting.

(e) Making Pulls

When the drill has completed a run, or the bit becomes blocked, the drill should be stopped and the drill rods and barrel removed from the hole. Each time a pull is made, the drill rods should be stacked and the core barrel emptied and inspected to see that it has been completely cleared of core and the bit is in good condition. Bits often lose their gauge while still retaining a good cutting face. The loss of gauge and consequent loss of clearance will increase core losses, as well as causing difficulty when a new bit is put into the hole. Such occurrences (and the associated wear on the core barrel) can be reduced with the use of core barrel reaming shells. Experienced operators usually keep several bits having varying amounts of wear on hand, and frequently change bits to fit the hole conditions and get the utmost production out of each bit as well.

Before the tools are returned to the hole, the logger should fit the broken pieces of core together, measure the amount of core recovered, and determine if any core has been lost. If core has been lost, the logger should look over the notes on the drilling characteristics of the run and examine the core to locate where and why the loss occurred. The suspected reasons for the core loss should be recorded with a question mark.

Sec. 306.05 Factors Affecting Recovery of Core

(a) General

When unusual core losses occur, the driller should attempt to determine the cause and correct the problem. Frequently this is due to the presence of soft, broken, or unconsolidated layers within a formation of otherwise competent rock. The significance of this type of material to the overall performance of the foundation was discussed in Sec. 306.01, and its importance cannot be overemphasized.

Where this is not the case, however, core loss is usually the fault of using improper drilling procedures or there is equipment malfunction. The following is a list of circumstances that contribute to unnecessary loss of rock core:

(1) Drilling Too Fast

Improper rotation speed and too rapid feed of drill bit.

(2) Water Pressure

If too high, it may erode the core; if too low, it may allow the bit to clog. A pressure gauge is recommended.

(3) Rotation of Inner Core Barrel

Causes adjacent lengths of core within the barrel to grind against each other.

(4) Whipping of Drill Rods

Worn guides allow the drill head and rods to wobble, grinding up the core.

(b) Information On Core Losses

By carefully observing the action of the drilling rig, an alert operator can obtain considerable information about the condition of the material being drilled, the position of contacts, cavities, weak zones, etc. The driller should be constantly on the alert to note anything revealed by the action of the rig that may enable him to explain any losses in the core. The action of the pumps and variations in the color and flow of the return drilling fluid are also indicators of changes in the nature and consistency of the rock being drilled. The operator shall inform the Geologist of the changes in drilling conditions as they occur, based on the action of the rig, and may supplement these observations by reference to the core after it is pulled.

(c) Loss of Drill Water

Loss of drill water may indicate the presence of voids, fractured zones, or clay seams, and it is important to record the details of this occurrence. The depth at which drilling water is lost, the range of depth over which such losses occurred, and the depth at which the water is regained shall be recorded. Close observation by the driller is necessary to locate these points accurately.

SECTION 307 BORING RECORDS

During the progress of each boring, the Geologist/crew chief shall keep a continuous and accurate log of the materials encountered and a complete record of the operation involved, in accordance with Sec. 800. The information shall include at least the following data:

Sec. 307.01 General Information

General information required is as follows:

(1) Date

(2) Name of Operator, and, if applicable, the Drilling Company.

(3) Location and number of hole, referenced to survey data and the elevation of the top of the boring.

(4) Type of drill and any special equipment.

(5) Elevation of ground water table and suspected perched water tables, marsh or swamp water, or adjacent river, stream, or other waterway surface.

(6) Elevation of each subsurface material boundary.

(7) Length of sample recovered.

(8) Soil or stratum represented by the sample.

(9) Soil shall be described in accordance with Sec. 305.02.

Sec. 307.02 Cased Borings

In addition to the general information required in Sec. 308, soil borings will require the following information:

(1) Diameter and description of casing.

(2) Weight and height of drop of hammer, and number of blows used to drive the casing to each successive foot (0.3 m) of elevation.

(3) Elevation of top of each different material penetrated.

(4) Elevation of the bottom sampler at start of driving or pushing for each sample.

(5) Elevation to which the sampler was driven or pushed.

(6) Elevation of bottom of boring.

(7) Weight and height of drop of hammer and number of blows used to drive the split spoon (SPT) sampler for each foot (0.3 m) of sample.

(8) Length of sample obtained.

(9) Soil shall be described in accordance with Sec. 305.02.

Sec. 307.03 Core Borings

In addition to the general information required in Sec. 308, core borings will require the following information:

(1) Elevation of bedrock.

(2) Type of core barrel and diameter of core.

(3) Length of core recovered for each length drilled, with percentage of recovery and RQD (Rock Quality Determination, defined as the percentage recovery from the total run in intact core lengths of at least 4 inches (100 mm), assuming a minimum N size core).

(4) Elevation of each change in type of bedrock.

(5) Elevation of bottom of hole.

(6) The bedrock shall be described in accordance with the procedure for classification, as given in Sec. 306.02.

SECTION 308 PACKING AND DELIVERY OF SAMPLES

Undisturbed dry samples require special handling and transportation. Consult with the appropriate laboratory authority for the conventions to be followed .

Ordinary dry samples are to be packed in pasteboard cartons with the sample jars in an upright position. On each box shall be clearly marked the project number, boring number, and sample numbers contained. The samples shall be accompanied by a letter of transmittal, as outlined in Sec. 801.

Where rock cores are taken, the cores will be packed in the core boxes which have been prepared for this material. The cores should be labeled to indicate the beginning of the run and the end of run. Cores secured from drilling boulders are to be marked and placed in core boxes, if boulders are sizable. It is recommended that cores be photographed in the core boxes, along with a legible identification card.

The Geologist should carefully preserve these samples for visual inspection or physical examination by the District Bridge Engineer or others, if deemed necessary. The samples are to be retained for approximately 12 months after the structure has been opened to traffic. The samples shall be accompanied by a letter of transmittal, as outlined in Sec. 801.

SECTION 309 SUBMITTAL OF REPORTS

Immediately upon finishing the field work, the Geologist will complete all drill logs, reports, and recommendations, and submit them to the Central Office Division that requested the investigation. Copies of the reports and supporting data should be sent to the Central Office Materials Division.

For bridge site investigations, computer disk of CADD information, drill logs and reports will be submitted to the Central Office Divisions of Bridge Location and Design (Hydraulics Section) and Materials with the BC report. The BC report may address the potential for scouring based on the Geologist's historical knowledge of the behavior of the native soils to be found within the streambed. The District Bridge Office should retain only copies of the CADD information when needed. The District Geologist should retain the bridge situation plan, in case additional information is needed.

SECTION 310 SPECIAL DESIGNS

Sec. 310.01 Wick Drains

Wick drains are a form of composite drain (corrugated or indented plastic core encapsulated in a nonwoven geotextile sheath) that is mechanically inserted into the ground at design specified intervals to lessen the time needed for consolidating slow draining soil masses. This product was developed as an equivalent to sand drains.

In determining the amount of settlement that will take place in a soil mass due to some load condition (embankment or spread footing), it is assumed that only vertical drainage is taking place. By using wick drains, consolidation takes place much faster due to the fact that the wick drains are providing radial drainage as well as vertical drainage. The amount of time reduction that will take place by using wick drains will be dictated by the spacing of the drains. The closer the wicks are spread, the lower the Radial Time Factor will be, thus giving a higher average degree of consolidation for simultaneous vertical and radial drainage.

Wick drains may be placed in a square or triangular pattern and spaced generally not less than 3 ft. (1 m) on center nor more than 12 ft. (4 m) on center. The standard one-dimensional consolidation test results and boring log data for the area to be treated are the only data necessary to design the optimum spacing of the wick drains.

Sec. 310.02 Stone Columns

Stone columns are columns constructed of highly densified, open-graded stone that are used to support embankments, light weight structures, and retaining structures in areas of soils with very low bearing capacity.

The construction of the stone column involves the use of a large vibrator, called a “vibroflot", that uses high pressure water jets or compressed air. The high frequency vibroflot and water or air jets liquefy the already soft soil and allow the vibroflot to be lowered into the ground, maximizing the space for the column. As the vibroflot continues down, the water or compressed air flushes the displaced soil and maintains an annular space around the vibroflot. The vibroflot maintains a specified frequency of the vibrator on the vibroflot, and amperage is measured to keep that level of frequency. If an increase in amperage is needed to maintain the specified frequency, then a firm foundation for the column has been reached and further progression of the vibroflot is ceased.

An open graded stone (Virginia Sizes 3, 357, and 57 have been used) is then deposited in the annular space between the vibroflot and the soil. The stone is then compacted by the vibroflot. Once the stone at the base of the column is compacted, the rest of the column is built in approximately 2 ft. (0.6 m) sections up to the top of the ground.

The size and spacing of the column is determined by the size of the load the column will support, the amount of settlement in the system that can be allowed, and the degree of improvement in bearing capacity and shear resistance required in the soil. The columns are generally placed in a square or triangular pattern and range in size from 15 to 48 in. (0.4 to 1.0 m) in diameter. The spacing of the columns is generally from 2 to 15 ft. (0.6 to 4.5 m) on center.

For the design of stone columns, the information needed is the standard one dimensional consolidation test results, shear strength data (either laboratory test or field vane shear test), and boring log data for the area to be treated.

Sec. 310.03 Geotextiles

Geotextiles are a product that has come into widespread use in the civil engineering field since the mid 1960's.

Geotextiles come in nonwoven and woven styles and are composed of propylene, ethylene, polyester, or nylon yarn.

The nonwoven textiles are most useful in drainage applications, due to the size of the openings in the fabric and the way they are constructed. The nonwoven fabrics are generally used with an indented plastic core to make composite drains and as a trench liner in underdrains and french drains. The tensile strength of the nonwoven fabrics is low to moderate, and they should be used with caution, because of the high level of elongation that will take place in reaching their peak strength.

The woven textiles are most useful in applications where it is necessary to separate materials (such as an aggregate base material from a marginal strength clay), or to stabilize an embankment or earth slope. The woven fabrics give moderate to high tensile strength with low elongation.

Depending on the size and orientation of the openings in the fabric, the woven textile can also have useful application as a drainage material. Uses of woven geotextiles have been to stabilize embankments placed on marshes, stabilizing pavements placed on marginal strength subgrades (thereby reducing undercut excavation quantities), and as a separator.

Geogrids are a form of geotextile that have very high tensile strength with low elongation. The geogrids have been used mostly in earth slope stabilization, stabilizing embankments placed over pipe culvert trenches, and stabilizing embankments placed on marginal foundation soils. They are beginning to be used to increase strength of the aggregate base layer in pavement structures.

Geomembranes are geotextiles that are essentially solid sheets of plastic that are available in various thicknesses. Primary uses for geomembranes are as moisture barriers for earth dams and cut-off walls, pond liners, and as a containment medium at the base of salt storage bins.

The Federal Highway Administration publication, Geotextile Engineering Manual, is an excellent guide to the design of geotextiles for a variety of uses. The necessary information needed for design of geotextile systems is the standard one-dimensional consolidation test, shear strength data (either laboratory test or field vane shear test), grain size analysis, and boring log data.

Sec. 310.04 Settlement Plates

Settlement Plates are typically employed for monitoring the settlement below embankments on soft ground. However, settlement plates may be used to monitor the performance of wick drains, the performance of dewatering operation, potential settlement caused by construction, etc.

Take elevation readings (to nearest hundredth of a foot or mm) when the pipe is extended or biweekly until fill is completed. Once filling has been completed, take readings at 1, 2, 4, 8,16, 24 days and biweekly thereafter until release for grading. Readings are recorded on the front of form TL-137, and the resulting elapsed days are plotted on the reverse side of this form. Evaluation of the readings by the Engineer will be the final and sole governing factor for releasing embankments for grading operation. Note: Additional Sheet may be added, if needed. See Sec. 803.67 for additional information.

SECTION 311 PLANT SAMPLING, TESTING, AND INSPECTION OF CENTRAL-MIXED AGGREGATE BASE, SUBBASE, AND SELECT MATERIAL

(Reference Secs. 208 and 209, Road and Bridge Specifications.) Aggregate base and subbase materials (and select material, when specified) will be mixed in a central mixing plant of the pugmill or other approved type, with the material being blended prior to or during mechanical mixing, in such a manner that will ensure conformance with specified requirements.

Sec. 311.01 General

The following instructions cover the sampling, testing, and inspection of dense graded aggregate base, subbase, and select materials for grading, Atterberg Limits, C.B.R., and other physical tests, except depth and density, which are covered in Sec. 314 herein. Samples of dense graded aggregates for soundness tests (AASHTO T104) will be handled as outlined in Sec. 204.02 herein. See Sec. 206 for Independent Assurance sampling requirements. (Aggregates paid for on a volume basis will be sampled as directed by the District Materials Engineer.)

Sec. 311.02 Equipment

(a) Plant Laboratory Equipment

Central-mixed aggregate laboratories and testing equipment shall be furnished by the Producer, except that rubber mauls and iron bowls for buffing of aggregates will be furnished by the District Materials Engineer. Plant production laboratories will be equipped, as outlined in Secs. 106.06 of the Road and Bridge Specifications. (Reference - AASHTO T87, T89, T90 and VTM-7, VTM-25, VTM-40)

(b) Regional CMA, or Multiple Use Laboratories

The Department reserves the right to require a laboratory conforming to the requirements of Sec. 106.06 at each plant which is processing material for Department use; however, use of a single regional laboratory to serve several plants in a given area may be permitted, provided such multiple use does not adversely affect the sufficiency and timeliness of the sampling and testing program at each plant. In the event a dispute arises over the practicality of multiple plant use of a single laboratory, such disputes are to be referred to the State Materials Engineer for resolution.

(c) Inspection of Plant, Equipment and Personnel

(1) Initial Plant Inspection

The plant will be inspected before production for compliance with specification requirements governing plants and testing equipment. A program of regular but unannounced inspection shall be scheduled and supervised by the District Materials Engineer at all central mix aggregate plants supplying dense graded aggregate or select material for State work. This inspection shall be conducted at any plant initially setting up and starting production, and at least once per year thereafter or as required. The purpose of this inspection is to determine that the plant, equipment and personnel meet specification requirements. A record shall be prepared on a checklist type form of all items covered during the plant inspections by the District CMA Monitor Technician. (See the standardized "C.M.A. Pugmill Plant Inspection Report" Appendix No. III A herein.)

(2) Regular or Routine Plant Inspection

The plant will be inspected periodically during production, including items such as stockpiles, equipment, control charts, sampling, testing and records kept by the Contractor's Technician. These inspections will be in addition to the initial or annual inspections noted in Paragraph (c)(1) above; will likewise be completely unannounced and shall be conducted by personnel of the District Materials Engineer's staff and/or by Central Office Materials personnel. The inspections are to be conducted for the purpose determining whether or not specifications and instructions are being followed by Contractor and personnel in the production, sampling, testing and inspection of central-mix aggregate.

The frequency of these latter plant inspections should be related to the overall quality of the plant equipment and competence of the plant personnel. Plants that have a record of continually producing good materials, being in excellent condition and manned by well trained personnel may be inspected as seldom as once a year. However, plants with poor records should be inspected more often. Periodic inspection of all plants at the same frequency regardless of record is not recommended.

A plant inspection report is to be issued on the forms available for this purpose immediately upon completion of this inspection. The forms are to be completely and accurately filled out by the District Materials personnel conducting the inspection, noting any and all discrepancies and any corrective action taken by the inspection personnel. Thereafter, this report shall be reviewed by the District Materials Engineer or his representative and copies of the report retained for District use. A copy of plant inspection reports shall be forwarded to the State Materials Engineer.

Unfamiliar Department and Industry personnel shall be requested to show evidence of their certification to visiting representatives of the Materials Division.

(d) Maintaining Records

Materials personnel shall keep a diary of plant visits, observations, and comments made to the Contractor's representative.

(e) Field Nuclear Equipment

Nuclear equipment necessary for performing nuclear field density tests, when specified, is available through the Central Office Soils Laboratory. Instructions for the operation, administration, and safety in the use of this equipment are detailed in Secs. 105.02, 105.03, and 105.04 herein.

Sec. 311.03 Approval of Job-Mix

The District Central-Mix Aggregate Monitor shall determine that the job-mix formula and all material proposed for use have been approved by the Materials Division.

Sec. 311.04 Documentation of Tonnage Material

For details of documentation of tonnage material and the bonded weigh program, see Secs. 106.04(e) and 800 herein.

Sec. 311.05 Sampling Central-Mixed Aggregates

Sampling of central-mixed aggregate will be in accordance with the procedures designated herein. In addition to Independent Assurance samples, samples and tests of the material shall normally consist of 2 types; i.e., (1) Production Control (Producer) and (2) Acceptance(Monitor).

(a) Quality Control (Producer) Samples and Tests

Quality control samples are those obtained by the Producer's Certified Technician at the plant and tested in the Plant Laboratory for grading, Atterberg Limits, cement content, and moisture content. When these materials are shipped directly to the road after mixing at the pugmill, sampling of materials is to be in accordance with the quality assurance program, as outlined below.

In the production of these materials, the optimum moisture content, plus or minus (2) percentage points, will be required. It will be necessary for the District Materials Engineer to determine the average optimum moisture content of the average aggregate produced, and to supply this information to the Producer's Certified Technician.

A statistically acceptable method of randomization is to be used to determine the time and location for taking the stratified random sample. See the Central-Mixed Aggregate Plant Certification Study Guide for an approved randomization method. Testing will be in accordance with the Road and Bridge Specifications. The frequency of sampling shall be at a rate of 4 samples per 2000 ton (2000 metric ton) lot (4000 ton (4000 metric ton) lot may be used when the normal production exceeds 2000 tons (2000 metric tons) per day). The sample shall be obtained from the approximate center of randomly selected quadrants of truckloads of material. Samples shall be taken after the material has flowed through the pugmill with optimum moisture, plus or minus (2) percentage points. The size of the sample should be 30 to 40 lbs (15 to 20 kg).

Separate the sample into 2 approximately equal portions by processing the sample through the sample splitter or split by the quartering method. Run a grading test on half of one of the split portions and use part of the other half of the split portion for the liquid and plastic limits tests. The portion to be used for the Atterberg Limits must be dried at a temperature not to exceed 140F. (If no Monitor sample is being taken, as detailed in Paragraph (b) below, the Producer's Technician must still split the sample as noted above before running the tests on one of the split portions.)

(b) Independent Assurance (Monitor) Samples and Tests

Independent Assurance (Monitor) Samples are those obtained at the central-mixed aggregate plant by the Producer's Certified Technician in the presence and under the observation of the Department's Monitor, and tested in the District or Central Office Laboratory, at the Monitor's discretion. These samples are tested for grading, Atterberg Limits, cement content (if applicable), and moisture content.

During the first production week, if production is under 30,000 tons (30,000 metric tons), 4 monitor samples per type mix will be randomly selected from each plant in a manner such that one person can handle the monitoring requirements of several plants. Thereafter, 2 monitor samples per production week will be taken for production of under 20,000 tons (20,000 metric tons), 3 monitor samples per week for production of from 20,000 to 29,999 tons (20,000 to 29,999 metric tons), 4 monitor samples per week for production of from 30,000 to 49,999 tons (30,000 to 49,999 metric tons), 5 monitor samples per week for production of from 50,000 to 79,999 tons (50,000 to 79,999 metric tons), and 6 monitor samples per week for production of 80,000 tons (80,000 metric tons) or more. (A "production week" is defined as a total of 5 production days.) Whatever the production tonnage may be, each monitor test should represent at least 500 tons (500 metric tons) of material. Where the same material is used as 2 different types, it shall be considered as one material.

This rate of monitor sampling is mandatory, and it is the responsibility of the District Materials Engineer to see that it is accomplished. Should the monitoring effort fall behind the required frequency of sampling and/or testing, the District Administrator is to be advised immediately. Sufficient personnel are to be provided for the monitoring effort. The Department's Monitor will observe the manner in which sampling is performed by the Contractor. Not only is the "when", "where", and "how" of taking the sample important, but also the care taken to properly reduce the sample to testing size. The Monitor directs when the sample shall be taken. He/she shall observe the Contractor's Technician taking and splitting (or quartering) the sample into 2 approximately equal portions. The Monitor takes one-half of the sample to serve as the Independent Assurance sample. The Contractor's Technician will perform the test on the other half, which is to be considered as the next quality control sample for the Contractor. (See Paragraph (a) above.)

(c) Comparison of Test Results

Weekly statistical comparisons will be made between the production control grading and Atterberg Limits test results and those of the Department's monitor sample. This comparison should be made by the District Materials Engineer or Monitor, using the printout data available from the Information Systems Division via the District terminal. This data is provided in the following manner:

Case = 1, Regular Monitor and Production Comparison,

Case = 2, Production and Monitor Match Comparison, or

Case = 3, Both Reports.

The above data is computed using the method outlined in VTM-59.

In the event a statistical comparative analysis of the Contractor's test results and the Department's independent assurance tests indicate a statistically significant difference in the results, and either of the results indicate that the material does not conform to the grading and Atterberg Limits requirements of the contract, an investigation will be made to determine the reason for difference. The results of the investigation are to be sent to the State Materials Engineer for use in preparing the annual report to FHWA. The sampling and testing procedures and laboratory test equipment (both the Producer's and the Department's) should be checked. If differences still cannot be explained, then the Department may call for the referee system to determine final disposition of the material. If it becomes necessary to implement the referee system, refer to Sec. 209.10 of the Road and Bridge Specifications to determine the sampling details. For additional details of test comparisons, see Sec. 315.01 (e) herein.

(d) Treating with Cement

When these materials are treated with cement at the pugmill, sampling of materials will be the same, as outlined in Paragraphs (a) and (b) above. The cement content is determined in accordance with VTM-40 and Sec. 307.05(b) of the Road and Bridge Specifications.

(e) Computations for Aggregate and Water in Pugmill Mixed Materials

Outlined herein are the standard acceptable guidelines for computing the various amounts of aggregate and water needed (with or without cement) to determine pay items, etc., when aggregate base, subbase, and select materials are pugmill mixed. This method is to be used along with the tests for moisture determination, such as with the "Speedy" Moisture Tester. Accordingly, corrections for excess moisture should be made as indicated herein.

(1) For example, assume 1000 tons (1000 metric tons) of material shipped containing 10 percent total moisture. (The test for total moisture must be made on a sample of material obtained by the Producer's Technician, after all water has been added to the mix in the pugmill, and after the material is ready for job shipment.) Assume also that the average optimum moisture of the material, furnished by the District Materials Engineer, is 6 percent. The allowable moisture would be:

6% + 2% = 8% (Specifications).

(2) Moisture Correction:

$\frac{1000}{1.10}$ tons = 909.1 tons (909.1 metric tons) of dry aggregate.

(3) Pay Quantity:

909.1 tons x 1.08 = 981.8 tons (981.1 metric tons) of aggregate.

This is the total combined tonnage that should be computed as the amount eligible for payment. Notes should also be made on the computerized test report, Form TL-52B, and on the Weighperson's Daily Summary Report, Form TL-102A, showing the average optimum moisture and the total moisture, in order that proper corrections for payment can be made later in the net weight recorded on the weight ticket and in materials notebooks.

If material is stockpiled after production, it will be necessary to make test for total moisture and record results on forms listed above at the time of shipment of material to the project. If moisture of the aggregate in the stockpile is below the minimum required (optimum minus 2 percent), the stockpiles must be sprinkled to bring the moisture within tolerance. Computations for the pay quantity should be carried out to the same decimal point as the pay item.

(f) Stockpiling After Mixing

When these materials are stockpiled at the pugmill after mixing and before shipment to the project, independent assurance (monitor) sampling will not be performed while the Producer is stockpiling material. Instead, when material is shipped to the project from the stockpile, independent assurance (monitor) samples will then be taken, as outlined in Paragraphs (a) and (b) above. If the material was not pugmill mixed prior to stockpiling, then it will be necessary to run the material through the pugmill prior to production and acceptance sampling and shipping.

(g) Samples of Select Material for C.B.R. Test

Samples of select material for C.B.R. tests will be taken at the minimum rate of one per project, whether the material is processed or local.

(h) Quality Assurance Testing

Quality Assurance testing of plant produced materials is not performed on separate samples, but as an interpretation of the data from the IA test. This interpretation is performed within the aggregate database program.

Sec. 311.06 Sampling Material from the Road

Sampling aggregate base, subbase, and select material from the roadway for grading and Atterberg Limits tests normally will not be required, unless the material has not received acceptance testing at the source prior to shipment, as outlined in Secs. 311.05(a) and (b) above, or unless the material being placed on the road indicates contamination or segregation, regardless of prior acceptance testing.

If roadway sampling becomes necessary, it is to be done immediately after road mixing has been completed and prior to compaction. The Project Inspector, when properly trained and experienced, can take samples. Samples of the material shall be obtained from 3 points in the roadway. These shall be at the center and approximately 4 ft. (1 m) transversely from the outer edges of the course being laid. The material from the 3 points is to be taken the full depth of the course being laid. The sides of the hole should be kept as nearly vertical as possible. The material should be placed on a canvas or other surface of sufficient size, thoroughly mixed, and quartered or split to obtain the proper size sample.

Roadway samples will be tested in the District or Central Office Laboratory, at the discretion of the District Materials Engineer, and at the rate of sampling previously specified in Secs. 311.05(a) and (b) above. Samples of select material for C.B.R. tests will be taken at the minimum rate of one per project, or more often as needed for control, if these tests have not been performed prior to the receipt of the material at the job site. The same rate of sampling outlined above applies to aggregate used as shoulder material.

Arrangements should be made for a daily pickup of samples taken by the Inspector, if it becomes necessary to sample material from the roadway.

SECTION 312 SAMPLING SOILS AND GRANULAR MATERIALS FOR CEMENT, ASPHALT, OR LIME STABILIZATION

Where soil-cement, soil-asphalt, or soil-lime stabilization is to be used on a new location, on an existing road, or on a change in grade, representative samples of the material in the road or of the soil to be stabilized are to be submitted to the District or Central Office Soils Laboratory for tests. Samples should be taken from each different soil type encountered. If the materials in the existing roadway or on the new location are reasonably uniform, one sample should be sufficient. If select material is to be used in the stabilization, the provisions of Sec. 304.03(d) herein should be applied.

In some cases, aggregate base, subbase, or select materials to be treated may be open graded, requiring excessive amounts of stabilizing agent acting as an expensive filler, or resulting in a product with an excessive amount of voids if the cement content is held to acceptable limits. The recommended grading on critical sieves for these materials is given below and should be adhered to as closely as possible.

Sieve Number	Minimum Percent Passing
4 (4.75 mm)	55
10 (2.00 mm)	37
-10/+200 (-2.00 mm/+75µm)	25 (Minimum % retained between these sieves.)

Select material may require additional care to maintain the material close to these limits without requiring tighter grading controls.

SECTION 313 IDENTIFICATION AND SIZE OF SAMPLE TO BE SUBMITTED

Each sample submitted to the Materials Division is to be accompanied by 2 Form TL-11 cards. One card should be placed in an envelope and attached to the outside of the bag, and the duplicate card submitted by mail. Form TL-11 shall be completely filled out including the amount of material represented by the sample. This can be either volume, lineal feet (meters) (Sta. to Sta.), tonnage ,or percentage, as the case may be. Further instruction for Form TL-11 will be found in Sec. 800 herein.

Size of sample to be submitted is as follows:

(1) Local Pit or Select Material - 30 to 50 lbs.(15 to 25 kg) (One bag).

(2) Material To Be Used in Embankments - 20 to 30 lbs. (10 to 15 kg) (One bag).

(3) Material for C.B.R. Test (From Soil Survey or Source) - 75 to 100 lbs. (40 to 50 kg) (2 Bags if all material will pass 3/4 in. (19.0 mm) sieve. 3 Bags if considerable amount of plus (+) 3/4 in. (19.0 mm) material is present).

(4) Pugmill Material (Regardless of Where Tested) - 30 to 40 lbs. (15 to 20 kg) (One bag).

(5) Subbase or Base Material From Road - 20 to 30 lbs. (10 to 15 kg) (One bag).

(6) Material for Soil-Cement Stabilization - 75 to 100 lbs. (40 to 50 kg) (2 Bags).

(7) Material for Soil-Asphalt or Soil-Lime Stabilization - 30 to 50 lbs. (15 tp 25 kg) (One bag).

SECTION 314 ROAD SAMPLING, TESTING, AND INSPECTION

The following section contains instructions for the density and depth control of compacted embankments and finished subgrades (density), cement or lime stabilized subgrade, consisting of material in-place or imported material other than aggregate base, subbase, or select material, treated or untreated aggregate base, subbase, and select material, and aggregate shoulder materials.

Sec. 314.01 Density Control

(a) General

(Reference Secs. 303.04, 304, 305.03, 306.03, 307.05, 308.03, and 309.05, Road and Bridge Specifications.) See Sec. 206 herein for Independent Assurance sampling requirements. See Sec. 207 herein for possible waiver of compaction tests on special projects.

Compaction is defined as "the process by which a soil mass is reduced in volume by the application of loads, such as rolling, tamping, or other means." Since compaction and settlement each bring about a closer arrangement of soil particles, it is evident that proper compaction will prevent subsequent natural settlement of an embankment or pavement layer under its own weight. It is, therefore, essential that proper control be exercised to ensure that the correct amount of moisture and compactive effort are applied when constructing an embankment or densifying a subgrade or pavement layer.

The density of a soil is defined as the weight per unit volume (lbs. per cu. ft.) (kg per m^3) in a oven-dry condition.

Optimum moisture is that moisture content of a soil at which maximum density can be obtained under the standard compaction procedure.

The percentage compaction is the ratio of the dry weight of the soil (density), as placed by mechanical means, to the maximum dry weight (density) of the same soil compacted in the Laboratory under a standard procedure (AASHTO T99, Method A), or as modified. This ratio may also be determined using the One-Point Proctor Method, VTM-12, in lieu of AASHTO T99. However, in case of determining field density by the nuclear method, the percentage compaction is determined in a somewhat different manner, as outlined in Sec. 314.01(c)(1) herein.

Before field control of compaction can be exercised, it is necessary that the Laboratory maximum density and optimum moisture content for each type soil or aggregate (pavement base or subbase materials) be determined in advance of the compaction operation.

In addition to information available on soil survey reports, it may be necessary to submit representative samples of the soil to be compacted to the District Laboratory, unless the One-Point Proctor Method is used for this determination in the field. Samples submitted to the District Laboratory should be from 30 to 50 lbs. (15 to 25 kg), or one full bag. If C.B.R. tests are to be performed, 2 full sample bags are required. The following information shall supplement that normally given on Form TL-11 which accompanies the sample:

(1) Horizontal limits (by station number) represented by the sample.

(2) Vertical limits (in feet or meters) represented by the sample.

(3) Visual description of material (Example: a highly micaceous silty sand).

(b) Compaction and Determination of Field Density

(1) Use of Laboratory and One-Point Proctor Density - As noted above, in computing the percent of compaction in the field, it will be necessary to compare the density, as determined in the field, to either a standard laboratory density, as determined by AASHTO T99 (VTM-1), or by the One-Point Proctor density, as determined by VTM-12, unless otherwise noted herein.

(2) Equipment Needed for Field Density Test - The equipment necessary for performing field density tests is available through the District Materials Engineer. To provide instruction and assistance to the Project Inspectors who operate nuclear gauges for measurement of density of

soils, aggregates, and other paving materials, a Materials Technician is available in each District for this purpose. See Secs. 105.02, 105.03, and 105.04 herein for details and safety precautions for the use of nuclear equipment.

(3) Control of Moisture - Control of moisture is most important in obtaining proper compaction of soils and granular materials. Too little moisture will require more compactive effort to obtain the desired density. If there is too much moisture, the maximum density cannot be reached regardless of how much the soil is rolled. The Inspector should perform frequent moisture tests, in order to be sure that the soil has correct moisture content.

Materials having a moisture content above optimum by more that 30 percent of optimum are not to be placed on a previously placed layer for drying, unless it is shown that the previously placed layers will not become saturated by downward migration of moisture in the material. If moisture is not within the specified tolerances, then the lift will have to be aerated or moisture added, as the case may be. All moisture tests taken are to be recorded and become a permanent part of the record of the project.

It is suggested that the "Speedy" Moisture Tester be used for expediency in conducting these tests, except when the soils are heavy clays, in which case the field stove method should be used.

The above instructions apply primarily when conducting field density tests by one of the methods other than the nuclear density method. When using the nuclear density method, moisture will be determined, as outlined in Paragraph (c)(1) below.

(c) Methods of Field Density Determination

(1) Nuclear Moisture-Density Method

The nuclear moisture-density method of field density determination, when specified, will be conducted in accordance with VTM-10 and Secs. 303 and 304 of the Road and Bridge Specifications. The entire scope of nuclear testing is also outlined in detail in the Department's Nuclear Moisture-Density Testing Procedure Manual, and will not be repeated here.

Nuclear density tests of embankments, subgrade, cement or lime stabilized subgrade, and backfill for pipes and culverts will be conducted using the Direct Transmission Method of testing. The nuclear density obtained is compared with either the Laboratory density, AASHTO T99 (VTM-1), or the One-Point Proctor density, VTM-12, to determine the percentage compaction.

Nuclear density tests of aggregate base, subbase, and select materials, both untreated and treated with cement or lime, for pavement as well as shoulder material, will be conducted using the Backscatter, Control Strip Method of testing. The nuclear density obtained in the test sections is compared with that of the corresponding control strip. In this case, the Laboratory density (VTM-1) or the One-Point Proctor density (VTM-12) is not normally used. On some small projects, such as turning lanes, crossovers, bridge approaches, etc., the District Materials Engineer may waive the Control Strip Method in favor of the Direct Transmission Method of testing, and compare the density obtained with the Laboratory (VTM-1) or One-Point Proctor (VTM-12) density.

Moisture tests of soils will be made directly using the nuclear device, rather than as outlined in Paragraph (b)(3) above.

If there is a breakdown in the nuclear testing equipment, then the Inspector should continue checking density using other conventional methods.

(2) Sand-Cone Method

When specified, field density tests by the Sand-Cone Method will be conducted in accordance with AASHTO T191. Next to the nuclear method, this is probably the most widely used method of determining field density. Briefly, it involves finding the weight of a sample and measuring the volume occupied by the sample prior to removal. This volume may be measured by filling the space with a material of predetermined weight per unit volume, in this case sand. The percentage compaction will be determined by comparing the field density obtained with the Laboratory, AASHTO T99 (VTM-1), or the One-Point Proctor, VTM-12, density.

(3) Rubber Balloon Method

When specified, field density tests by the Rubber Balloon Method will be conducted in accordance with AASHTO T205. Percentage compaction will be determined by comparing the field density obtained with the Laboratory, AASHTO T99 (VTM-1), or the One-Point Proctor, VTM-12, density.

(4) Other Methods

Other approved methods may occasionally be adopted for use in determining field density. The procedures outlined in pertinent instructions will be followed.

(d)Frequency of Field Density Tests

The frequency of field density testing shall be as outlined herein. Again, it should be emphasized that the rates given for testing are the minimums considered desirable to provide effective control of material under ideal conditions, and more testing than that specified should be done, if deemed necessary by the Engineer.

(1) Embankments and Finished Subgrades

The minimum number of field density tests required will be one for each 10,000 cu. yds. (8,000 m^3) or less of embankments, with the following additional requirements:

(a) For fills from 500 to 2000 ft. (150 to 600 meters) in length, one density test will be required for each 6 in. (150 mm) layer within the top 5 ft. (1.5 m) of fill.
(b) For fills less than 500 ft. (150 m) in length, one density test will be required for every four (4)-6 in. (150 mm) layers from bottom to top of the fill.

The terms "embankment" and "fill" as here used are intended to encompass the entire roadway in width, under construction between right-of-way lines, regardless of whether the roadway is single or dual lane. For example, a dual lane fill would be considered as a single fill. However, each separate linear embankment or fill will be considered as a separate item and tested at the above specified rate, separately and independently of adjoining fills. Location of test run is to be staggered, so that the entire length, width, and depth of the fill is covered by tests. The top, bottom, and middle of fills, and any necessary points in between, shall each be tested. When testing is not being conducted, the Inspector is to visually observe lifts being placed to ensure that proper placement and compaction procedures are being used.

In the finished subgrade in both cut and fill sections, a minimum of one test shall be made for each 2000 linear feet (600 m) of subgrade for each roadway (full width).

The amount of rock present in the embankment that will preclude conducting the density test should remain flexible, and should be at the discretion of the Project Inspector. However, it should be understood that if it is possible to conduct a test, then the test should be run.

The District Nuclear Technician will conduct a continuous program of instruction for project personnel in running density tests and will inspect all density testing equipment used by Project Inspectors, to ascertain that it is kept clean and properly calibrated.

The District Nuclear Technician should observe the Project Inspector conduct a density test, and should make such corrections as are necessary. An initial inspection should be made as soon as possible after a project starts, and as often thereafter as necessary. The Technician should also inspect density test reports prepared by the Inspectors, to determine if sufficient tests and proper coverage have been made, that reports are properly prepared and completed, and that all pertinent information has been included on the test reports.

(2) Cement or Lime Stabilized Subgrade

When the subgrade, consisting of material-in-place or imported material other than aggregate base, subbase, or select material, is stabilized with cement or lime, one density test is to be conducted for each one-half (1/2) mile (1 km) of stabilization per paver (mixer) application width. In other words, each separately applied width of stabilization, regardless of roadway width, will require a separate series of tests.

The tests should be started from 25 to 100 ft. (10 to 30 meters) from the beginning or end of the project, with the remaining tests being spaced at variable intervals not exceeding the linear spacing noted above. The tests should be located in the approximate center of the applied width, but occasionally should be staggered across the applied width at random locations to check density, particularly near the edges of the stabilization. Care is to be taken not to set up a uniform pattern of tests.

The density recorded at each location will be considered as the density for the applied width of stabilization, and extending one-fourth (1/4) mile (0.5 km) longitudinally in each direction from the test location. If tests are made at closer intervals than that specified, the test data will apply to a point extending half-way between the test point and the next test point on either side.

(3) Aggregate Base, Subbase, and Select Materials

Density tests of aggregate base, subbase, and select material, whether treated with cement or lime or untreated, will be taken the same as outlined in Paragraph (d)(2), except that the tests will be performed on each compacted layer of the pavement course, if the course is applied in more than one layer. Also, when using the nuclear method, each recorded test specified above shall consist of the average of 5 readings, the location of which shall be at randomly selected sites.

When using the nuclear method, a roller pattern and control strip must be set up for each layer or lift placed, in order to establish the maximum density required before testing of the test section.

(4) Aggregate Shoulder Material

Density tests of aggregate shoulder material are to be taken as outlined in Paragraph (d)(3) above, except that the tests will be performed on alternating sides of the road each one half (1/2) mile (1 km).

(5) Backfill for Pipes and Box Culverts

A minimum of one test every other compacted lift on alternating sides of the Structure not to exceed 300 linear feet (90 m). This test pattern is to begin from the top of bedding material to 1 foot (0.3 m) above the top of the structure.

(6) Backfill for Abutments, Gravity and Cantilever Retaining Walls

A minimum of two tests every other lift up to 100 linear feet. (30 m) Testing shall be performed behind the backwall at a distance from the heel no farther than a length equal to the height of the structure plus 10 feet (3 m).

(7) Mechanical Stabilized Earth (MSE) Walls

Less than 100 linear feet (30 m), a minimum of one test every other lift. The testing will be performed a minimum distance of 8 feet (2.5 m) away from the backface of the wall, to within three feet (1 m) of the back edge of the zone of the select fill area. Stagger the test sites throughout the length of the wall to obtain uniform coverage. Testing will begin after the first two lifts of select fill have been placed and compacted.

Walls more than 100 linear feet (30 m), a minimum of two tests every other lift not to exceed 200 linear feet (60 m).

(8) Backfill for Minor Structures

To include Drop Inlets, Junction Boxes, Manholes etc. A minimum of one test per structure shall be performed. At the discretion of the engineer more tests may be necessary due to the dimensions or type of structure to be backfilled.

(e) Corrections for Areas Outside of Tolerance

If any areas are found to be outside of specification tolerances for density, the corrections are to be made in accordance with the particular Road and Bridge Specification relating to the material in question.

(f) Reports

Results of job acceptance density tests in the field are to be reported on Forms TL-53, TL-54, TL-55, and TL-124 (for the nuclear methods), Form TL-125 (for the sand-cone method), and Form TL-125A (for the One-Point Proctor Method of determining maximum density). All test reports must be completely filled out, giving all required information. All tests, both passing and failing, must be reported. The failing test report must show what action was taken. When tests are not run due to gravel, muck, rock, or whatever reason, a report should be submitted giving reasons for the tests not being conducted, and such information as the length (station to station) of roadway not tested, as well as depth or elevation in the fill not tested. Independent Assurance density tests will be so marked on the form in bold letters (INDEPENDENT ASSURANCE DENSITY TEST) , and the results of I.A. density tests will also be tabulated on Form TL-136, in addition to the forms noted above.

See Sec. 800 for details of completing and distributing these forms.

Sec. 314.02 Depth Control

(a) General

(Reference Secs. 305.05, 305.07, 306.10, 307.08(b), 308.04, and 309.06, Road and Bridge Specifications.) See Sec. 206 herein for Independent Assurance sampling requirements. Job acceptance depth tests are to be made by a person other than project personnel, except as indicated below. This person shall be an impartial party, namely the District Materials Engineer or a member of his/her staff.

In the event the District Materials Section is unable to perform the required depth tests of a pavement layer in time to avoid a delay to the Contractor in placing additional material above this layer, it will be satisfactory for the Project Inspector to make the required depth tests and record the data obtained for the project records. However, in this event, it will be necessary for the Project Inspector to document in the records: (1) that the District Materials Section had first been requested to perform the depth tests, and (2) the reason why the District Materials Section was unable to perform the test without causing delay. The Project Inspector shall give all depth test data to the District Materials Engineer for inclusion in the depth report.

Measurements are to be taken at random for each course after completion of the course depth as the work progresses. This should not be construed as requiring that the entire project be completed before conducting depth tests. Depth tests should be made as sections of the project are completed. It shall be the responsibility of the Inspector or Project Engineer to notify the District Materials Engineer when any part of the construction is ready for depth tests, but not before first conducting check tests at the project to be reasonably assured that the proper depths of material have been placed. The volume of material measured on the basis of cubic yards (cubic meters) compacted in place is to be computed from the length and width shown on the plans and the average depth of the material on the entire project, determined from measurements taken at the below noted intervals, measured longitudinally along the surface.

(b) Frequency of Depth Tests

For the purpose of determining depth, and to define areas of deficient or excessive depth, job acceptance depth tests are to be made, as outlined in VTM-38. Materials to be tested by VTM-38A include cement or lime stabilized subgrade, consisting of material-in-place or imported material other than aggregate base, subbase, or select material. Materials to be tested by VTM-38B include (1) treated or untreated aggregate base, subbase, and select material, and (2) aggregate shoulder material.

For Method VTM-38A, one depth test is to be conducted for each one-half (1/2) mile (1.0 km) of stabilization per paver (mixer) application width. In other words, each separately applied width of stabilization, regardless of roadway width, will require a series of tests.

The tests should be started from 25 to 100 ft. (10 to 30 m) from the beginning or end of the project, with the remaining tests being spaced at variable intervals not exceeding the linear spacing noted above. The tests should be located in the approximate center of the applied width, but occasionally should be staggered across the applied width at random locations to check density, particularly near the edges of the stabilization. Care is to be taken not to set up a uniform pattern of tests.

The depth recorded at each location will be considered as the depth for the applied width of material and extending one-fourth (1/4) mile (0.5 km) longitudinally in each direction from the test location. If the tests are made at closer intervals than specified, the test data will apply to a point extending half-way between the test point and the next test point on either side.

In cases in which the depth determined is deficient or excessive beyond the allowable specification tolerances, it will be necessary to define or bracket this area with additional depth tests, as outlined in VTM-38A.

Tests will be made in turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc., at the discretion of the Engineer.

For method VTM-38B, the project is to be divided into lots, with each lot stratified, and the location of each test within the stratified section determined randomly. A lot of material is defined as the quantity being tested for acceptance, except the maximum lot size will be 2 miles (4.0 km) for each paver application width. The randomization procedure used will be at the direction of the Engineer. (See VTM-38 for example.) Samples will be taken from the lot at the following rate:

Lot Size	No. of Samples Required
0 - 1 Mile (0 – 2 Kilometer)	2
1 - 1 1/2 Miles (2 – 3 Kilometer)	3
1 1/2 - 2 Miles (3 – 4 Kilometer)	4

In the case of aggregate shoulder material, use the same linear frequency of testing as used on the mainline, except alternate the tests from one side of the road to the other.

Samples will be taken from turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc., at the discretion of the Engineer. These samples will not be taken at random; however, care is to taken not to set up a uniform pattern. The tolerance for an individual test result shall apply.

It is not the intent of this procedure to prohibit the sampling and testing of the material at any location which is visually determined to be out of specification tolerance for an individual test.

In some cases, select material or similar material may be used in certain undercut sections, etc., in depths exceeding that shown on the plans as the uniform design depth of the pavement structure for the entire project. In these cases, the District Materials Section will be responsible for checking only that uniform depth shown for the entire project (usually 12 in. (0.3 m) or less). It will be the responsibility of the Inspector to ensure that the depths of materials used for backfill, etc. in certain isolated sections are maintained.

(c) Corrections for Areas Outside of Tolerance

If any areas are found to be outside of specification tolerances for depth, the corrections shall be made in accordance with the particular section of the Road and Bridge Specifications relating to the material in question.

(d) Reports

Results of job acceptance depth tests of the above noted materials shall be retained as part of the permanent project records. The data may be kept in the form of a worksheet. Those depth tests that fail to meet specification requirements and subsequent delineation and/or correction determinations are to be recorded on Form TL-105. Results of Independent Assurance depth tests shall be tabulated on Form TL-136. See Sec. 800 for details of completing and distributing these forms.

SECTION 315 UNIFORM GUIDE FOR CENTRAL-MIXED AGGREGATE QUALITY ASSURANCE AND CONTROL

Quality assurance is a system of quality control, testing, and acceptance procedures used to assure that a product meets specifications. The following section is intended as a guide for interpreting and administering the specifications for central-mixed aggregate. This guide is to be considered as a supplement to the control and acceptance procedures previously outlined herein. It is not intended to relieve Department Monitors and Inspectors of other duties required to obtain proper quality inspection of central-mixed aggregate.

Sec. 315.01 Responsibility of Materials Division

(a) Mix Design Approval

The central-mixed aggregate mix design (job-mix formula) shall be approved or disapproved, as outlined in Secs. 106.01 (c) and 800, prior to the start of mixing operations.

(b) Personnel Certification

The Department will provide classroom technical instruction, examination, and certification for all appropriate personnel. The State Materials Engineer shall direct the administering of examinations and certifications to Technicians and Inspectors.

Written examinations shall be administered by the District Materials Engineers for certification of Department and Industry personnel in their respective Districts. The written examination shall be monitored by the District Materials Engineer or his/her assistant, and an accurate accounting of all examination papers shall be maintained.

All written examinations shall be prepared, graded, and recorded under the direction of the State Materials Engineer.

Reexamination and recertification will be required 4 years from the date the certificates are issued. The status of the certification for Inspector and Technician is valid only for the specific responsibilities and privileges granted to the bearer and name appearing on the certificate issued. If at any time an Inspector or Technician is found incapable of performing his or her duties as prescribed herein, he or she shall not be allowed to take part in the production of central-mixed aggregate being manufactured for State use. The certification issued shall be rendered invalid on the recommendation of the District Materials Engineer.

(c) Inspection of Plant, Equipment, and Personnel

(1) Initial Plant Inspection

The plant will be inspected before production for compliance with specification requirements governing plant and testing equipment. A program of regular but unannounced inspections shall be scheduled and supervised by the District Materials Engineer at all central-mixed aggregate plants supplying aggregate materials for State work. This inspection shall be conducted at any plant initially setting up and starting production, and at least once per year thereafter or as required. The purpose of this inspection is to determine that the plant, equipment, and personnel meet specification requirements. A record shall be prepared on a checklist type form of all items covered during the plant inspections by the District Central-Mixed Aggregate Technician. (See Appendix III-A.)

(2) Regular or Routine Plant Inspection

The plant will be inspected periodically during production, including items such as stockpiles, equipment, weighing operation, sampling, testing, and records kept by the Contractor's Technician. These inspections will be in addition to the initial or annual inspections noted in Paragraph (c)(1) above, will likewise be completely unannounced, and shall be conducted by personnel of the District Materials Engineer's staff and by Central Office Materials personnel. The inspections are to be conducted for the purpose of determining whether or not specifications and instructions are being followed by Contractor and personnel in the production, sampling, testing, and inspection of central-mixed aggregates.

The frequency of these latter plant inspections should be related to the overall quality of the plant equipment and competence of the plant personnel. Plants, that have a record of continually producing good materials and of being in excellent condition and manned by well trained personnel, might be inspected by the Materials Division Technician as seldom as once a year. However, plants with poor records should be inspected more often. Periodic inspection of all plants at the same frequency regardless of record is not recommended.

A plant inspection report is to be issued on the forms available for this purpose immediately upon completion of this inspection. The forms are to be completely and accurately filled out by the District or Central Office Materials personnel conducting the inspection, noting any and all discrepancies and any corrective action taken by the inspection personnel. In addition to copies of the report retained for District use, a copy of plant inspection reports shall be forwarded to the State Materials Engineer.

Unfamiliar Department and Industry personnel shall be requested to show evidence of their certification to visiting representatives of the Materials Division.

(d) Maintaining Records

Materials personnel shall keep a diary of plant visits, observations, and comments made to the Contractor's representative. The District Materials Engineer also must furnish the Contractor with the optimum moisture content of the aggregate being produced.

(e) Material Acceptance

Accept the product in accordance with specifications, based upon the Producer's test results, provided such results are statistically comparable (VTM-59) to the Department's monitor test results and provided the material passes a visual examination for contamination and segregation at the job site. The sole purpose of the monitor sample taken by the Department is to verify the accuracy of the Producer's testing program.

(1) Monitor Sampling

For details of frequency and method of monitor sampling, see Sec. 311.05(b).

(2) Comparison of Test Results

See Secs. 311.05(c) and 315.01(g) herein for additional details of test result comparison. If the comparisons indicate the monitor test results are not in agreement with the Producer's results, investigations will be made to determine the source of difference. If the differences can be determined, the material will be accepted, adjusted, or rejected in accordance with the specification. If the difference cannot be explained, the Department may call for the referee system to determine the final disposition of the material. In the event it is determined that the

Producer's test results are not representative of the product, the Department will take such action as it deems appropriate to protect the interest of the Commonwealth.

(3) Referee System

Provide a referee system which may be invoked at the request of the Contractor or Department, and which will involve utilization of the test results obtained from samples secured from the road. See also Sec. 311.05(c) herein and Sec. 209.10 of the Road and Bridge Specifications.

(f) Monitor's Duties

During the time of the Monitor's visit to the plant, he/she will pick-up the Producer's test results and the District Materials Engineer's copy of the daily summary sheets, Form TL-102A. The forms are reviewed for correctness and legibility. The contract number(s) and tonnage(s) are obtained from the weigh sheets and recorded on the input form, Form TL-52A, which is submitted to the computer terminal for input and storage . No display is needed for this entry.

The original and one copy of the test report, Form TL-52B, will be returned through the terminal automatically. The report should be reviewed for correctness. The original should be put in the District Materials Engineer's project folder. The other copy should be forwarded to the Contractor/Producer that is producing the material. If there is more than one contract on the lot, only one lot copy is to be sent. One copy of the lot should also be put in a plant file. This is the only distribution that is needed. The materials notebook only requires a one line entry identifying the period of time over which the material was shipped (Fr.______________ To ______________), grading or type mix, total tonnage, and source.

In case of nonconformance to the specifications, a copy of the test report will be furnished the Prime Contractor.

(g) Monitor's Test

The success of the Q.A. Program will be determined to a large extent by the effectiveness of the monitoring effort. Deficiencies revealed through this effort should be addressed promptly and decisively. The results of the Monitor's tests are recorded on a monitor report form, Form TL-52C, and submitted to the computer terminal. No display is needed for this entry. A request is made for the production and monitor comparisons for each plant to the terminal operator. When making this request, use dates that include at least 7 monitor results, Also, if there is a change, begin with the date of the change. A report comparing the production results with the monitor results will be returned. When the report returns, review it for correctness and send one copy to the Contractor/Producer by way of the Monitor. If the results are not in agreement, an investigation should be made to determine the reason for differences. (See also Secs. 311.05(c) and 315.01(e)(2) herein.) Suggested checks are:

(1) Check to see if the monitor test results meet the specifications for Average and Standard Deviation.

(2) Check the Producer's result on the rate of the monitor sample to see if the 2 results are comparable.

(3) Check to see if one of the systems is indicating a trend (consistently fine, coarse, erratic, etc.)

(4) Check sampling and testing procedure.

(5) Check testing equipment.

When the next comparison is requested, send the prior monitor comparison data to the State Materials Engineer for review.

Sec. 315.02 Responsibility of Central-Mixed Aggregate Producer

(a) Materials

The Central-Mixed Aggregate Producer shall assume the responsibility for the quality control and condition of all materials used in central-mixed aggregate, as well as the handling, blending, and mixing operations, in accordance with Secs. 208 and 209 of the Road and Bridge Specifications. The Producer shall assume the responsibility for the initial determination and all necessary subsequent adjustments in proportioning of materials used to produce the specified central-mix. At any time during the plant operation, after initial setup, that sample failure occurs, immediate adjustments will be made. If these adjustments do not correct cause of failure, the plant shall be stopped and recalibrated.

(b) Personnel

All sources supplying central-mixed aggregate to the Department shall be required to have present during the initial setup, for all subsequent adjustments of the plant, and at all times during production for each job-mix, a Certified Central-Mixed Aggregate Technician, as outlined in Secs. 208.03 and 209.06 of the Road and Bridge Specifications. Such Technician shall be capable of designing, sampling, testing, and adjusting the mixture.

(c) Equipment

The Producer shall be responsible for providing and maintaining a plant laboratory and testing equipment, as outlined in Sec. 106.06 of the Road and Bridge Specifications. The Producer will be required to build a platform from which to take samples from the truck bodies.

(d) Performance of Sampling, Testing, and Recording of Central-Mixed Aggregate

The production control samples and tests are to be taken and performed by the Certified Central-Mixed Aggregate Technician, as outlined in Sec. 311.05(a) herein.

The Producer shall be responsible for recording test results and maintaining quality control charts. The Producer shall furnish the Department's Monitor copies of the test results on forms furnished by the Department and maintain current control charts at the plant for review by the Department. The Producer shall likewise maintain all records and test results associated with materials production; e.g., hydraulic cement, etc.

(e) Notification of Production

The Producer shall notify the District Materials Engineer when production is to start or resume after a delay.

(f) Assisting Monitor

The Producer shall obtain a sample at the request of the Monitor and analyze one-half of the sample. The Department will analyze the other one-half. This sample will be used as the next production control sample. See Sec. 311.05(b) for additional details of performing this sampling.

SECTION 316 STABILIZED OPEN GRADED BASE MATERIAL

Sec. 316.01 General

Job acceptance permeability tests of stabilized open graded base material will be performed in accordance with VTM-84. Sampling shall occur after asphalt stabilized material has been in place overnight and after cement stabilized material has cured sufficiently to permit coring.

Sec. 316.02 Frequency of Tests

Initial sampling for permeability tests will be at the rate of three (3) 6-inch (150 mm) diameter cores taken at approximately even intervals over the first one mile (1.5 km) of stabilized open graded base material placed in one pass of the paver. Samples shall not be taken within two (2) feet (1 m) of the edge of the layer or directly over any underdrain or trench in the subbase or subgrade.

Additional permeability sampling and testing may be waived by the District Materials Engineer if initial tests are passing and no changes occur in the mix design, compactive effort, or visual appearance of the material. Further testing may be necessary if changes occur in the gradation of the material or asphalt content.

If a change occurs, sampling will be at the same rate as initial sampling.

If localized areas of the stabilized open graded base material are suspect, a minimum of two (2) 6-inch (150 mm) diameter cores will be taken from the area for permeability testing and the average coefficient of permeability will be used for acceptance or rejection.

For investigative purposes, a minimum of one sample is required.

Filling of holes will be with a stabilized or unstabilized open graded material placed in a single layer and tamped until no further consolidation occurs within the hole. The finished material will be leveled to the grade of the surrounding material and all remaining loose material will be removed. Unstabilized material used to fill the holes shall be Aggregate No. 57, 68, 78, or 8. Stabilized material, if used, shall be of any cement or asphalt cement concrete material approved for Department use.

Sec. 316.03 Reports

Results of job acceptance permeability tests all be reported on Form TL-51.

All test reports must be completely filled out, giving all required information. All tests, both passing and failing, must be reported.

See Section 803.32a for details of completing and distributing these forms.

SECTION 317 SUMMARY OF MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

Following is a condensed tabulation showing the minimum requirements for acceptance testing of central-mixed aggregate. See also Secs. 205 and 206 for additional details governing minimum sampling and Independent Assurance sampling.

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
1. Embankments				
(a) Density, Any Method	303.10	One test per 10,000 cu.yd. (8000 m^3) or less plus: for fills from 500 to 2000 ft. (150 to 600 m), one test per 6 in. (150 mm) layer within top 5 ft. (1.5 m) of fill; or, for fills less than 500 ft. (150 m) one test per every four (4) - 6 in. (150 mm) layers bottom to top of fill.	Roadway	When tests are not run due to gravel, muck, rock, etc. give sta. and depth on report in lieu of test, with reason. For nuclear test, use Direct Transmission Method, VTM-10. See Note 4 for reports. If there is breakdown in nuclear testing equipment, continue density tests using other approved methods.
2. Finished Sub-grade (Both Cut and Fill Sections)-				
(a) Density, Any Method	305.03.	One test per 2000 lin. ft. (500 m)	Roadway of roadway (24 ft.)(7.3 m).	For nuclear test, use Direct Transmission Method, VTM-10. See Note 4 for reports. If there is breakdown in nuclear testing equipment, continue density tests using other approved methods.

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
3. Stabilized Subgrade (Mat'l.-in-Place or Imported Mat'l., Other Than Agg. Base, Subbase, or Select Mat'l.)-				
(a) Density, Any Method	307.06 & 306.09.	One test per 1/2 mile (1.0 km) per paver(mixer) application width.	Roadway.	For nuclear test, use Direct Transmission Method, VTM-10. See Note 4 for reports. Tests to be located in approximate center of applied tests. If there is width. Care is to be taken not to set up uniform pattern of tests. If there is breakdown in nuclear testing equipment, continue density tests using other approved methods.
(b) Depth	307.08(b) & 306.10.	One test per 1/2 mile (1.0 km) per paver (mixer) application width.	Roadway.	Tests to be conducted by VTM-38A. Tests to be located in approximate center of the applied width. Care to be taken not to set up uniform pattern of tests. Deficient or excessive areas of depth shall be as defined in VTM-38A. See Note 3 for reports. Tests in turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc., at discretion of Engineer.

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
4. Central-Mixed Aggregate (Treated or Un-treated) (a) Base, Subbase, and Select Material-				
(1)C.B.R. (On Select Material Only)	208.02	One-75 to 100 lb. (40 to 50 kg) sample per project, or more often as needed for control, on processed or local material, to District or Central Office Laboratory.	From processing or mixing plant or roadway	If material is treated with additive, sample must be taken without additive included. See Note 2 for reports.
(2) Grading and Atterberg Limits	209.02, 209.08, 208.02, 208.05.	Producer: Four (4) 30 to 40 lb. (15 to 20 kg) samples per 2000 ton (2000 metric ton) lot (4000 ton (4000 metric ton) lot may be used when normal production exceeds 2000 tons (2000 metric ton) per day). Samples taken in stratified random manner.	From processing or mixing plant. Technician.	Same as Item 4(a)(1). Samples to be taken and tested by Producer's Certified Central-Mixed Aggregate Producer shall keep records of tests on Form TL-52A and maintain quality control charts and tests results will be reported on Form TL-52B.

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
4(a)2 Cont'd		Monitor: During first production week, if production under 30,000 tons (metric tons), 4 samples per type mix. Thereafter, sample for production as follows: Under 20,000 tons (metric tons), 2 samples per production week; 20,000 to 29,999 tons (metric tons), 3 samples per production week; 30,000 to 49,999 tons (metric tons), 4 samples per production week; 50,000 to 79,999 tons (metric tons), 5 samples per production week; and 80,000 tons (metric tons) or more, 6 samples per production week. Where same material used as 2 different types, it shall be considered as one material. Sample taken and split from Producer's sample, such that each half is not less than 15 to 20 lbs. (7 to 10 kg) Producer's half	From processing or mixing plant at time of shipment. Sampling from roadway normally will not be required, unless material has not received acceptance testing at source, or unless material being placed on road indicates contamination or segregation, regardless of prior acceptance testing.	Same as Item 4(a)(1). Sample taken by Producer's Certified Central - Mixed Aggregate Technician in presence of Monitor, and tested in District or Central Office Laboratory, at monitors discretion, and reported on Forms TL-32 and TL-52C. District Materials Engineer or Monitor will make weekly comparisons of production control test results vs. Monitor test results. See Secs. 311.05(c) and 315.01(e)herein for additional details. Select material not centrally mixed and aggregates paid for on a volume basis will be sampled as directed by the District Materials Engineer.

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
	considered as next production sample.			

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
(3) Density, Any Method	304, 309.04, & 308.03.	One test per 1/2 mile (1.0 km) per paver application width per layer. If testing by nuclear method, each test shall consist of average of 5 readings.	Roadway. Location of 5 nuclear readings at randomly selected sites.	For nuclear tests, use Backscatter, Control Strip Method, VTM-10. With nuclear method, set up roller pattern and control strip for each layer or lift placed. See Note 4 for reports. If there is breakdown in nuclear testing equipment, continue density tests using other approved methods.
(4) Depth	309.06 & 308.04.	Two (2) tests each paver application width from 0 to one mile (2 km), 3 tests each width from one to 1 1/2 miles (2 to 3 km) , and 4 tests each width from 1 1/2 to 2 miles (3 to 4 km). Maximum lot size is 2 miles (4 km) for each paver application width. Project divided into lots, each lot stratified, and location of each test within stratified section determined randomly.	Roadway.	Tests to be conducted by VTM-38B. Tests in turning lanes, acceleration or deceleration lanes, ramps, connections, crossovers, etc., at the discretion of the Engineer, and are not to be taken at random. However, care to be taken not to set up uniform pattern of tests. For these miscellaneous items, the tolerance for an individual test result shall apply. See Note 3 for reports
(b) Shoulder Material-				
(1) C.B.R. (On Select Material Only)	208.02.	Item 4(a)(1) governs.	Same as Item 4(a)(1).	Same as Item 4(a)(1).

CENTRAL-MIXED AGGREGATE
MINIMUM ACCEPTANCE SAMPLING REQUIREMENTS

MATERIAL AND TEST	ROAD AND BRIDGE SPECIFICATION REFERENCE	RATE OF SAMPLING	LOCATION FOR SAMPLING	REMARKS
(2) Grading and Atterberg Limits	209.02, 209.08, 208.02, & 208.05.	Item 4(a)(2) governs.	Same as Item 4(a)(2).	Same as Item 4 (a)(2).
(3) Density, Any Method	304 &305.06	Same as Item 4(a)(3), alternating sides.	Same as Item 4(a)(3).	Same as Item 4(a)(3).
(4) Depth	305.07.	Same as Item 4(a)(4), alternating sides.	Same as Item 4(a)(4).	Same as Item 4(a)(4).
5. Backfill for Pipes and Box Culverts -				
(a)Density , Any Method	302.07.	One test every third layer at random intervals.	Roadway.	Testing frequency may be altered according to uniformity of backfill material. For nuclear test, use Direct Transmission Method, VTM-10. See Note 4 for reports.

Note 1. See Section 304 herein for instructions for conducting soil surveys.

Note 2. C.B.R. tests are reported on Form TL-32; grading and Atterberg Limits tests on Form TL-52B if aggregate is plant mixed and test is job acceptance test. Other routine soils test, including grading and Atterberg Limits tests performed as part of soil investigation in District or Central Office Laboratory, are reported on Form TL-32, Form TL-34 (Soil-Bituminous Mixture), Form TL-35 (Soil-Cement Mixture), Form TL-36 (Soil Consolidation Test), and Form TL-37 (Soil Tri-Axial Test).

Note 3. Job acceptance depth tests are reported on Form TL-105.

Note 4. Job acceptance density tests are reported on Forms TL-53, TL-54, TL-55, TL-124, and TL-125A (Nuclear Methods), Form TL-125 (Sand-Cone Method), and Form TL-125A (One- Point Proctor Method).

Note 5. If there is a breakdown in the nuclear testing equipment, then the Inspector should continue checking density using other approved methods.

C. M. A. Pugmill Plant Inspection Report

Date:________________________________ Producer________________________________

Location ______________________________ District ________________________________

Plant Number ___________________________

Part I.

Condition of Equipment

1. Sample Splitter____
2. Motorized Screen Shaker with a set of large screens:

   3" (75 mm), 2 1/2" (63 mm), 1 1/2" (37.5 mm), 3/4" (19.0 mm), 3/8" (9.5 mm), #4 (4.75 mm), #10 (2.0 mm)____

   ____
3. Soil Grinder, pot and rubber maul (if applicable) ______________________________

   ____
4. Sink with running water____

   ____
5. Liquid Limit Device and grooving tool ____________________________________

   ____
6. Balance for fine aggregate analysis _______________________________________

   ___________________________Date of Calibration ____________________________
7. General Purpose balance for coarse aggregate analysis__________________________

   ___________________________Date of Calibration ____________________________
8. Motorized sieve shaker or attachment for motorized shaker _______________________

   ____
9. All 8" (203 mm) round sieves: No. 20 (850 µm), No. 40(425 µm), No. 60(250 µm), No. 80(180 µm), No. 100(150 µm), No. 200(75 µm)________________________________

   ____
10. Specify the type of drying apparatus that is being used___________________________

    ____
11. All other equipment, such as: moisture cans, square end shovel, counter brush,

    bread pan, etc. ____

    ____

    ____

    ____

    ____

Part II.

Sample Preparation and Procedures:

A. Is the sample preparation in accordance with VTM-25? ______________________________

____

B. Are all materials tested in accordance with the current AASHTO and/or VTM methods? ____

C. Is the size O.K.? ____

D. Is the portion of the sample finer than the No. 10 (2.00 mm) sieve being washed? __________

____

E. If the Liquid Limits and Plastic Limits are being run, is the sample being prepared and tested per AASHTO T89 & T90? ______________________________

____

F. Does the Technician have a record of test results? ______________________________

____

G. Are numbers drawn statistically just prior to beginning of production of a lot?

____

H. How are the numbers generated to represent the ton to be sampled? __________________

____

I. Is the sample being taken according to instructions? ______________________________

J. Is a permanent record of moistures being kept? ______________________________

K. Does the Plant Technician have current written instructions for sampling and testing material at Pugmills? ______________________________

____

L. Are control charts accurate and current? ______________________________

Technicians Signature ____

Certification Number ____

Part III

Inspection of Pugmill:

A. Type of Plants ____

B. Type of Feeder, if cement is being added ______________________________

____

C. On cement treated aggregate, is the titration test being conducted properly? ______________

D. Has the producer furnished a safe platform from which to take samples from the truck? ____________________

E. Stratified random samples are taken from ____________________

____

Part IV

	Departments Responsibility - "Monitor"	**Yes**	**No**
1.	Is plant inspected before production begins?	____	____
2.	Is optimum moisture furnished	____	____
3.	Are there unannounced periodic inspections and a record of same?	____	____
4.	Is a diary kept of plant visits?	____	____
5.	Is manner of sampling observed?	____	____
6.	Is manner of splitting observed?	____	____
7.	Has technician been furnished copy of comparison production and monitor test results?	____	____
8.	Are corrective measures taken when there are differences?	____	____

9. What action was taken to resolve differences? ____________________

____

____

____

C.M.A. Technician ____________________

This report has been reviewed and I concur with the findings of this inspection. Follow-up action to correct deficiencies (if any) will be taken.

____

District Materials Engineer or Assistant

Cy: State Materials Engineer